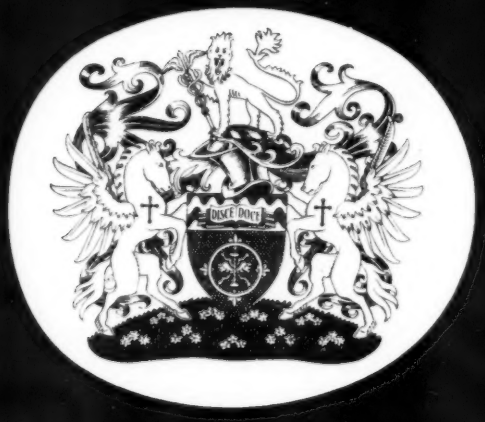

JOURNAL

JOURNAL

OF THE INSTITUTION OF ELECTRICAL ENGINEERS

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FIVE THOUSAND RENAMED

THERE ARE AT LEAST TWO REASONS FOR referring again on the *Journal's* first page to the oldest of our Specialized Sections. One is to call attention to the recent change in its title, which is the second since 1919, the year when it was born and was christened as the Wireless Section of The Institution. In response to the trend of the times it adopted, in 1944, the name Radio Section, and since October last, it has been known as the Radio and Telecommunication Section. Though less euphonious than its predecessors, this proper name goes some way to represent in words the full compass of the Section's technical interests; but it signifies a distinction without a difference, for telecommunication has been actively cultivated by the Section virtually from the time its field was first surveyed, although, for reasons of history and sentiment, papers concerned with communication by line were long the prerogative of our Ordinary Meetings. These Ordinary Meetings are the oldest type of Institution meeting at which scientific discussions take place, and they stretch back in unbroken succession to the founding of The Institution as The Society of Telegraph Engineers in 1871. The latest development affirms that line engineering is no more nor less suitable for discussion at Ordinary Meetings than many other important parts of the complex of electrical engineering. Like many titles, the new name for the Radio Section is itself only partly indicative of the crops growing in the Section's field; electronics, the universal herb for seasoning nearly all present-day electrical recipes, spreads thickly over it. Our Specialized Sections, however, are rightly classified by *application*: electronic engineering is made up of *techniques* which, although originally fostered by radio, find applications belonging to each of the four Sections.

A second reason is to congratulate the Section on attaining a membership in excess of 5000 professionally qualified members. In actual figures the membership of the Radio and Telecommunication Section on the 31st December, 1955, was 5160 members of all classes, of whom only 110 were Students. This last figure is in keeping with the Council's view that specialization should be avoided until an entrant to the profession has obtained his first qualification as a Graduate.

The names of the thirty-four members who have been Chairmen of the Section, freshly blazoned on the Common Room notice-boards, make impressive reading, and of this number no fewer than seven have in their turn been elected President of The Institution.

The intensive programme of regular Section meetings at which technical papers are presented and discussed do not always suffice to handle the wealth of new knowledge which the Section has to dispense, and the need has been met by periodical staging of technical Conventions. Thus the pent-up stream of information on war-time developments held by the sluice gates of the censor was methodically released at the Radiolocation Convention of 1946 and the Radiocommunication Convention of 1947, the records of whose transactions are to be found in the supplemental parts of the *Journal* issued at the time. Similarly in 1952 a Convention on the British Contribution to Television provided an opportunity to assemble in a single permanent record the technical developments made by British electrical engineers. Now we are approaching two further Conventions of the same stamp. These will take place in 1956, and they differ from the earlier ones in that they are both joint enterprises of the Radio and Telecommunication Section and of the Measurement and Control Section, a point that emphasizes the necessity of not treating 'radio engineering' as a watertight technology in its own right. In the Spring comes the Convention on Digital-Computer Techniques from the 9th to 14th April; in the Autumn the Convention on Ferrites from the 29th October to 3rd November.

Many of the papers submitted to the Papers Committee that come within the orbit of the Radio and Telecommunication Section are about research and a good proportion are sufficiently recondite to demand publication as monographs. There is always room for more short papers about practical development, installa-

tion or operation of new radio equipment. The papers on the Crystal Palace Television Station to be presented on the 4th April are good examples of this type. A greater number of authoritative papers on audio apparatus would probably be welcomed by the Papers Committee; a search through the *Proceedings* reveals, for example, that it is many years since a paper on high-fidelity sound reproduction has been published.

Apart from its technical activities, the Radio and Telecommunication Section leads a vigorous corporate life which is stimulated and cemented by the social events for which its Committee are responsible. In this firmament there are three fixed stars, respectively the Annual Dinner-Dance, the Summer Visit, and the Soirée, which is habitually held in the Institution building.

There is no compulsion on any member to join any Specialized Section, and the Section meetings are open to any interested member whether or not he belongs to the Specialized Section concerned. But clearly a man who finds that his life work as an electrical engineer lies for the most part within the province of a Specialized Section will receive much interest and satisfaction in joining it; not only will he receive news of all meetings, including those which may be arranged at short notice after the meetings card has gone to press, and be able to participate in the social functions arranged for Section members, but also he can take part in the election of the Section Committee. This election is an important responsibility affecting the whole Institution as well as the particular Section, for the Council and, especially, the Papers Committee are frequently guided in their decisions by the views of the Section Committee. The existence of a strong and representative Committee of the Radio and Telecommunication Section is indeed the best safeguard that The Institution is truly active in every endeavour in radio and communication engineering—both national and international—where it can usefully make its influence felt.

A Discussion Meeting

FAULT RECORDING INSTRUMENTATION

A Measurement and Control Section discussion on 'Fault Recording on a Power Supply System', which was opened by Mr. W. Casson and Mr. L. Csuros, was held at Savoy Place on the 1st November, 1955.

Opening Dissertation

MR. CASSON surveyed the general aspects of system disturbances and abnormal occurrences. When disturbances occur on a power-supply system it is important to obtain full information regarding the type of disturbance, its duration and its effect on the system. This information, in addition to various indications of protective-gear operation, switchgear operation, alarm schemes and other observations made during the disturbance, should include currents and voltages at different points on the system before and at various stages during and after the disturbance. From such information it should be possible to deduce the cause of the disturbance. Correct deduction is necessary, not only in order to avoid the danger of reclosure onto a fault or of recommissioning a circuit with a latent fault, thus leaving the system insecure, but also in order to enable the management to take steps to reduce, if possible, the risk of similar faults occurring.

He then dealt with the problems of measuring electrical quantities associated with these disturbances and occurrences. The quantities which can be measured include phase currents, residual and neutral currents, phase-to-neutral voltages, phase-to-phase voltages and residual voltages. Information on load and reactive-power-flow conditions may be important for determining the performance of directional relays. Mr. Casson described some special difficulties, such as changes in the character of faults, and pointed out that the quantities which have to be considered for recording cover a wide range, and the problems are aggravated by the fact that the period for which a record is required may vary from a few microseconds (e.g. lightning surge) up to a minute or so (e.g. disturbance leading to instability). A clear distinction has to be made, therefore, between the recording of power-frequency quantities and transients of shorter duration, and this has to be remembered in considering the performance of instruments. In deciding on the relative merits of the quantities to be recorded, it should be realized that there is a practical restriction on the amount of recording equipment which can be installed, and a choice has to be made of the quantities which are most important to ensure making best use of the equipment.

Mr. Csuros discussed the basic principles of recording instruments in two main groups. The first group is represented by those instruments which record only the maximum value of changing quantities over the period concerned. No indication is given of changes of the quantities recorded during the same period, nor is direct information obtained on the sequence of events. Examples of this group are the loose-pointer instruments, spark-gaps, instruments using remanent magnetism (such as magnetic links and more elaborate devices developed recently), the klydonograph, and the electronic surge-voltage recorder.

To the second group belong the chart or oscillographic

recording instruments of which the pen recorder is perhaps the first example. An oscillographic trace can be recorded photographically or mechanically. It was pointed out that in order to obtain full benefit of oscillographic recording, it is desirable to ensure that system conditions are recorded immediately before a disturbance in addition to those during and a short time after the disturbance. This problem can be solved by using memory schemes, e.g. supplying the elements of the oscillograph through an electric delay network in conjunction with a starting device which is operated direct from the power system. A cathode-ray tube with a persistent fluorescence provides another memory scheme in conjunction with a photographic camera which takes a picture of the traces still visible on the screen after a disturbance occurs.

Another ingenious scheme involves continuous recording and erasing on a suitable medium, and when a fault occurs the erasing is stopped. There are two principal applications of this scheme. The Masson-type instrument uses mechanical recording, whilst another scheme employs magnetic recording. After discussing the technical potentialities and limitations of the Masson type and the instrument recording magnetically, Mr. Csuros pointed out that the oscillograph and all fault-recording instruments recording on a chart require a starting device which is actuated by the system disturbance. These starting devices can be operated, for example, by voltage drop, rate of change of voltage, over-current, rate of change of current, neutral current, tripping or other relays of a protective scheme, etc.

Turning to the problems of practical application of the instruments, Mr. Csuros emphasized that there are many factors affecting the amount of fault-recording equipment to be provided on a power system. The maintenance of the recording equipment and collection of the information provided must be taken into account. Another factor is the cost of the equipment, and it is not generally possible to install all the equipment required to give full information. He invited discussion particularly on the controversial problems with which designers and operators of a power system are faced, including quantities to be recorded, the relative importance of the quantities, the choice of recorder, the usefulness of schemes incorporating some form of memory, the merits of different starting schemes, the practical extent of instrumentation that is permanently installed, transportable types for *ad hoc* studies and the evaluation of information on protective gear.

General Discussion

These opening remarks were followed by a full discussion in which fourteen speakers took part. The development of a recorder with a magnetic-drum memory device was described, and illustrated with slides; the speaker observed that this recorder used little power and imposed negligible burden on current transformers but had a restricted frequency response even when h.f. bias was used. The desired response greatly exceeded that customary in magnetic recorders for sound reproduction.

The cost of the memory features needed to secure a record of the first 0·05 sec of an occurrence was thought by one speaker to be disproportionate. A user of such equipment thought otherwise, citing some informative results obtained on the London supply network, but adding that a feature to indicate negative phase sequence would be valuable. A subsequent speaker said that electronic apparatus for such indications, in terms of voltage, was now being developed.

It was agreed that instruments should impose a small burden and present a constant impedance, and a fault-duration recorder having these attributes was illustrated. The basis was a high-speed relay and two chronometers. Given the sequence of events, many values could be derived by a network analyser, obviating complex recording.

Research apparatus, capable of good transient response, as opposed to instruments for power-frequency measurements in the field, was represented by a trailer-borne automatic cathode-ray oscillograph with photographic recording, capable of resolving circuit-breaker switching surges and similar transients to frequencies of up to 100 kc/s. This had a starting lag of 1 microsec and used no memory device. One speaker observed that a cathode-ray tube with a thousand hours' life would suffice for only about six weeks in an instrument on continuous service.

For the unattended monitoring of numerous feeders on an interconnected system, instruments on the Masson principle, with their slow consumption of chart paper, were considered advantageous, whilst the mechanical inertia of the movement, which was in any case small, could be partly discounted by skilled interpretation of the record. An improved model of the Masson recorder was demonstrated. The usual seven channels, each imposing a burden of about 2 VA, are now supplemented by twelve d.c. marker channels, whereby, for example, the sequence of operation of circuit-breakers and protective gear may be studied.

An electronic surge-voltage recorder using components of high reliability was described and illustrated. It photographs the indications of two moving-coil elements and of a chronometer driven from the supply. Mention was made of a scheme of fault location, popular in America, in which 1 kV impulses of 1 microsec duration are fed into the defective line at a rate of about 50 per second, and the echo displayed by radar techniques. Solid faults were thus located, but for such faults simpler methods already exist. Also in America, flashover had been located by using a microwave link to compare the time of reception of the resultant steep wavefront at two substations.

The meeting generally acknowledged the value of appropriate fault recorders for examining and rationalizing system behaviour, while two speakers, by recounting personal experiences, ensured that due credit was also given to more direct methods of diagnosis.

The History of Electrical Engineering

5. THE ORIGIN AND DEVELOPMENT OF THE ELECTRIC TELEGRAPH

Many members will be glad to read another article in the historical series from the pen of Mr. MacKechnie Jarvis; we apologize for the long interval that has occurred since the last instalment—on dynamo-electric machines—appeared. Here the story switches to communication, and the evolution of the embryonic telegraph. The reader will find himself in the pre-Institution era, but he may like to recall that it was for the advancement of telegraph engineering that The Institution was founded in 1871.

C. MACKECHNIE JARVIS, MEMBER

Towards the Electric Telegraph

THE basic requirements for an electric telegraph are: a source of electrical energy, means for originating and receiving signals and means for transmitting the signals between the two selected stations.

The earliest type of electrical generator was the cylinder influence machine, the development of which from the initial experiments of Otto von Guericke in 1672 has already been discussed in the first article in this series.

A means of conveying electrical intelligence from station to station arose out of the work of Stephen Gray, F.R.S., who at the time of his death in London in February, 1736, had to his credit more than ten papers in which he had described his experiments with influence machines and his researches upon the electrical properties of different substances. In collaboration with Granville Wheeler, F.R.S. (who died in 1770), he demonstrated the transmission of an electric discharge from such an influence machine through brass wires suspended by threads of silk, over distances in excess of 800 ft.

The invention of the Leyden jar in 1745–46 inspired further experiments of this nature, such as that of Shooters Hill, London, in 1748, the culminating experiment of a series carried out under the direction of Dr. William Watson, M.D., F.R.S., with the co-operation of Martin Folkes, President of the Royal Society, Lord Charles Cavendish, F.R.S., and others, in the course of which transmission of electricity over distances of 2½ miles with a return via the earth was established. By the end of the century, Augustin de Bétancourt (1760–1826) had, under the direction of Don Francisco Salvá (1751–1828) of Barcelona, increased this to a distance of 26 miles. It was but a short step to link the idea of transmission of the electrical fluid, to quote contemporary terminology, for considerable distances via wire and earth with the conception of communication through the same media.

A New Use for the Fluid—Some Electrostatic Systems

It is generally agreed that the remarkable letter which appeared in the *Scots Magazine*[1] over the signature 'C. M.' contained the first published account of a practical telegraph. It was based upon the use of a discharge of static electricity. The letter is dated Renfrew, 1st February, 1753, and describes a system requiring one wire for each character to be transmitted. With the wires were associated pith balls, which at the receiving end responded when the selected wires were electrified at the transmitter. The complete installation required an electrical influence machine at each end and the pith balls to be duplicated.

The identity of 'C. M.' has been the cause of much speculation and the letter is now generally attributed to Charles Morrison, a native of Greenock, who it is said was trained as a surgeon and later emigrated to Virginia, but the supporting evidence is scanty. One of the most interesting features of the letter, which is reproduced in full by Sabine,[2] is the proposal to insulate the wires.

> Some may perhaps think that, although the electric fire has not been observed to diminish sensibly in its progress through any length of wire that has been tried hitherto, yet, as that has never exceeded some thirty or forty yards, it may be reasonably supposed that in a far greater length it would be remarkably diminished, and probably would be entirely drained off in a few miles by the surrounding air. To prevent the objection, and save longer argument, lay over the wires from one end to the other with a thin coat of jeweller's cement. This may be done for a trifle of additional expense; and as it is an *electric per se*, will effectually secure any part of the fire from mixing with the atmosphere.

It will be noted that 'C. M.' was evidently unfamiliar with the experiments of Gray and Watson, which were fully described in the *Philosophical Transactions of the Royal Society* of the period.

Such a system comprising 24 wires was erected and operated for a time on a very small scale by Georges Louis Le Sage the younger (1724–1803) at Geneva in 1774, but a much more ambitious attempt was made by Don Salvá, who in 1795 proposed, in a remarkable paper before the Academy of Sciences of Barcelona, the establishment of a telegraph between that city and a town 13 miles distant. In this paper he envisaged the necessity for using 44 wires and is quoted as follows by Fahie,[3] in English translation from Saavedra:[4]

It appears, however, little short of impossible to erect and maintain so many wires, for, even with the loftiest and most inaccessible supports, boys would manage to injure them; but as it is not necessary to keep them very far apart, they can be rolled together in one strong cable, and placed at a great height. In the first trials made with a cable of this kind I covered each wire with paper, coated with pitch, or some other idio-electric substance, then, tying them together, I bound the whole with more paper, which effectually prevented any lateral escape of the electricity. In practice the wire cable could be laid in subterranean tubes, which, for greater insulation, should be covered with one or two coats of resin.

Salvá comments on the advantages of the submarine telegraph in the following words:

In no place can the electric telegraph (wires) be better deposited. It is not impossible to construct, or protect, the cables with their twenty-two (pairs of) wires, so as to render them impervious to the water. At the bottom of the sea their bed would be ready made for them, and it would be an extraordinary casualty indeed that should disturb them. . . .

In 1747, Watson, Bevis, and others in England, showed how the water of the Thames may be made to form part of the circuit of a Leyden jar, and this makes us consider whether it would not suffice for our telegraph to lay a cable of twenty-two wires only across the sea, and to use the water of the latter in place of the twenty-two return wires.

Salvá subsequently modified his system to operate over a single wire and an earth return and it is recorded that such a telegraph was in operation in 1798 between Madrid and Aranjuez, a town some 26 miles distant. There seems to be little known of the subsequent history of this installation and it may well be that, although originally erected under the patronage of Court circles, it was in fact little more than a plaything of ephemeral interest. We know, however, on the authority of Saavedra that Salvá read other papers before the Academy of Sciences in Barcelona, including one on the subject of 'Galvanism and its application to Telegraphy' on the 14th May, 1800, in which he followed Galvani and advocated the use of a number of frogs (legs?) as a battery. This paper was followed by a further paper read on the 22nd February, 1804, under the title of 'The Second Treatise on Galvanism applied to Telegraphy.' In this paper Salvá adopted 'Signor Volta's Column' as a source of electricity for purposes of a telegraph, working on the hydrolysis principle. He thus anticipated by some years the invention usually attributed to Sömmering in 1809. Salvá's voltaic telegraph does not seem to have been tried practically and the system will be discussed in connection with later developments.

That Don Salvá was living years in advance of contemporary knowledge there can be no doubt. In the space of less than ten years he had envisaged the use of a multicore cable with impregnated paper insulation, had conceived the possibility of installing this cable below the ground, and had foreseen the importance of a submarine telegraph. After demonstrating the successful operation of a system of telegraphy making use of charged Leyden jars, he went on to devise a single-wire system operated by a voltaic battery. With one exception,[8] Salvá's papers were not published and they were forgotten until rediscovered by Saavedra about 1880.[4]

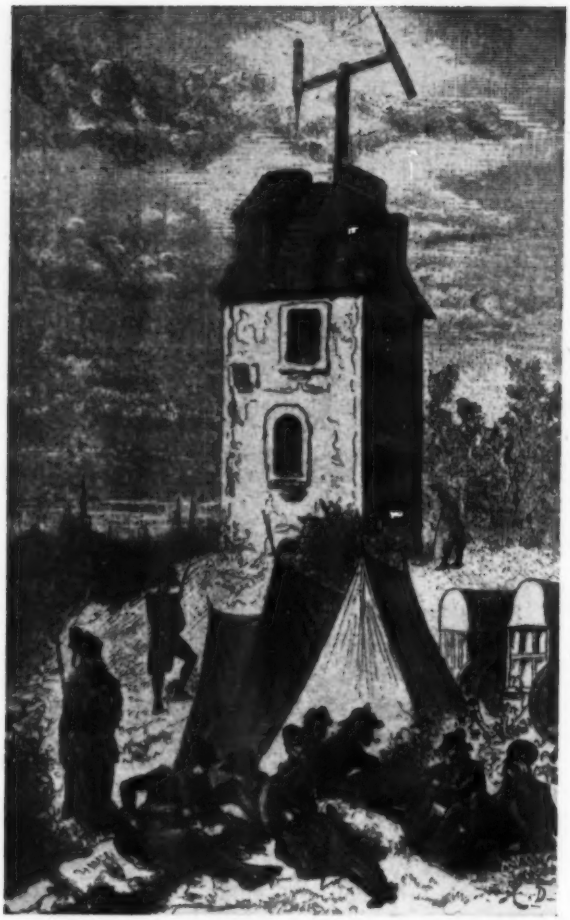
1 *Chappe's semaphore being demonstrated before members of the commission appointed by the National Convention of France, between Ménilmontant and Saint-Martin-du-Tertre on the 12th July, 1793*

In several other countries mention is made of small-scale experiments, and much has been written of the telegraph of Jean Alexandre of Paris, who is said to have developed the first step-by-step or ABC telegraph. Alexandre, in spite of powerful support, failed in his attempts to have his system adopted and preserved the secret of his invention. Beyond the fact that it had a dial lettered with the alphabet and was demonstrated in operation between two stations 15 metres apart on numerous occasions around 1802 we know nothing of it, and it seems not impossible that in action it was purely mechanical.

Introducing the Semaphore

We are now approaching a period which in England witnessed several determined attempts to persuade the Government to take an interest in the subject of electric telegraphy on a national scale, and it will be helpful, therefore, to examine the state of internal communication in this country (which incidentally was characteristic of European countries generally) at the close of the eighteenth century.

Naval and military operations had in successive ages



2 *Chappe's semaphore in action during the siege of Condé-sur-l'Escaut on the 30th November, 1794*

demonstrated the necessity for the speedy conveyance of intelligence. It is common knowledge that for many years beacons were employed to give warning of the approach of hostile forces, the system relying upon the successive firing of a chain of such beacons placed on high ground, between the coast and London.

In 1792 Claude Chappe (1763–1805) introduced in France his well-known semaphore which consisted of a system of arms pivoted to wooden pillars that were mounted on towers spaced up to 10 miles apart. The first large-scale trials were made in 1794 over a chain of such towers erected between Paris and Lille, a distance of some 148 miles. According to contemporary accounts the transmission time for the first short messages was about 13 minutes but this was appreciably reduced.

Chappe was not the first in the field, since the Englishman Robert Hooke (1635–1703), one of the most versatile men of his age, had proposed in 1684 a mechanical telegraph, which like many other of his inventions was not adopted.

France was in the throes of revolutionary activity and feared invasion from neighbouring Powers. Chappe could not have chosen a more opportune time, and it is not surprising that the success of the mechanical telegraph in France was immediate. Incidentally, the word 'telegraph' appears to have been coined by Miot of the French War Department, who applied it to Chappe's apparatus in 1793. News of the developments reached England, and in 1795 the British Admiralty was constrained to adopt a shutter-telegraph proposed by Lord George Murray, which was in operation between London and Dover from 1795 to 1816.

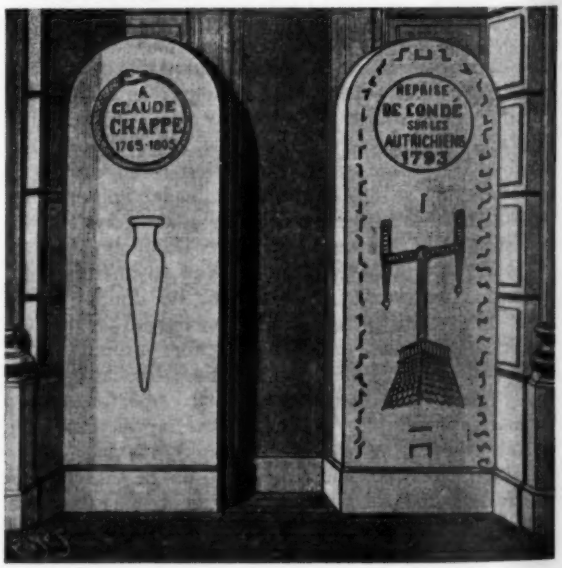
Unfortunately, during foggy weather the mechanical telegraphs were useless and it was necessary to employ post horses instead. In 1816 a change was made in favour of the semaphore invented by Admiral Sir H. R. Popham (1762–1820), which, although a great improvement, was nevertheless similarly affected by fog.

'Telegraphs of any Kind are now Wholly Unnecessary ...'

Meanwhile, between the years 1806 and 1814 Ralph Wedgwood (1766–1837), a member of the famous pottery family, endeavoured unsuccessfully to persuade the Government of the day to adopt an electric telegraph of his own invention. It is recorded that in 1814 he submitted his plans to Lord Castlereagh at the Admiralty but was later informed that 'the war being at an end, and money scarce, the old system (of shutter-semaphores) was sufficient for the country.'

3 *Memorial tablet to Claude Chappe preserved in Paris*

The tablet illustrates the symbols of his semaphore code and commemorates the inauguration of the system on an operational scale in 1793.



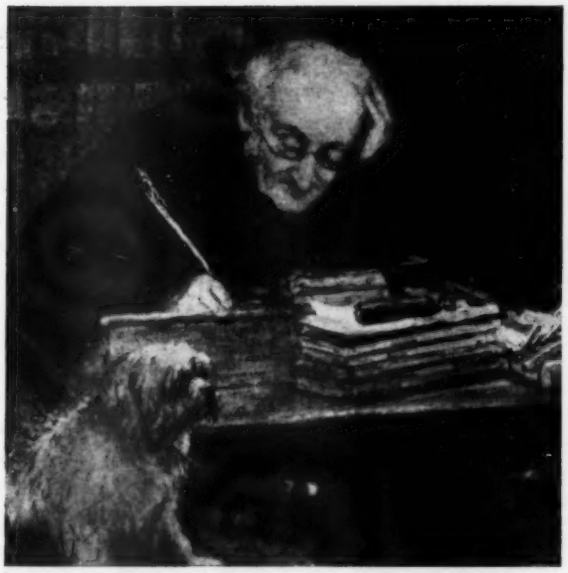
Wedgwood has left us no details of the system he employed and after 1815 appears to have dropped the idea in favour of work in other fields. It has been suggested by Fahie that Wedgwood probably employed the electrostatic principle, which was later favoured by Ronalds, whose own published account[6] of his work contains the following passage: 'Some German and American savants first projected galvanic or voltaic telegraphs, by the decomposition of water . . . but the other (i.e. static) form of the fluid appeared to me to afford the most accurate and practicable means of conveying intelligence. . . .'

In 1816, Sir Francis Ronalds, F.R.S. (1788–1873), carried out a series of experiments at his house at Hammersmith on a larger scale than was customary, and as a result he perfected a telegraph system of the synchronous type, employing static electricity as its operating medium. According to Highton,[5] Ronalds employed an electrical influence machine and a pith-ball electrometer in the following manner.

He fitted to the second-hand spindles of two clocks, dials having 20 letters and 10 numerals on them, and he covered each special dial with an aperture plate through which one letter and one numeral only were visible at any one time. The clocks were adjusted so that the letters synchronized, and one was placed at each station with a pith-ball electrometer suspended in front of the dial. For the purpose of experiment a metallic line was run to and fro between two substantial wood frames placed at opposite ends of the lawn, the resultant length being about eight miles (see Fig. 6). The line was normally electrified, and was discharged when it was desired to transmit a letter. The operator at the transmitting end would successively discharge the line as the appropriate characters appeared in the aperture of this instrument. At the receiving end the operator would similarly record the characters in view whenever the electrometer collapsed. That Ronalds was fully alive to the importance of telegraphy is shown by the utterances in his book.[6] He appreciated also the difficulty of dealing with wilful damage to the lines, in connection with which he wrote:

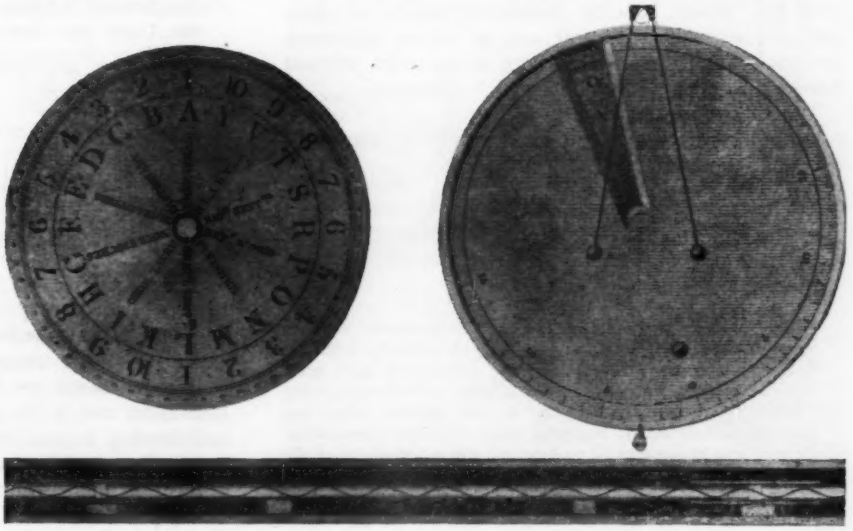
'Should they succeed in breaking the communication hang them if you can catch them, damn them if you cannot, and mend it immediately in both cases.'

After carrying out a large number of experiments with the overhead line, he explored the alternative of an underground system, a trial length of which he con-



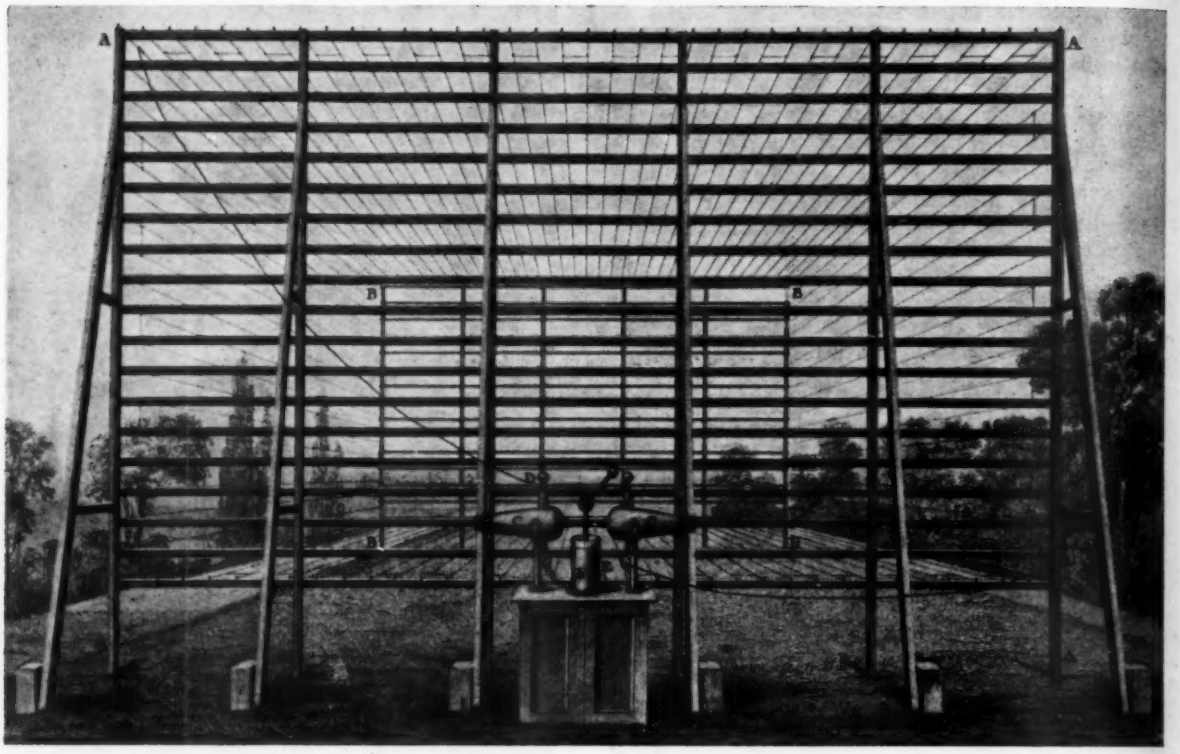
4 *Sir Francis Ronalds, F.R.S. (1788–1873), sometime Honorary Director and Superintendent of Kew Observatory*

He received the honour of knighthood on the recommendation of W. E. Gladstone in 1870 in acknowledgment of his 'early and remarkable labours in telegraphic investigations'.



5 *Ronalds's drawing of the rotating indicator disc and fixed orifice plate, fitted to the clocks used in his synchronous telegraph*

Note the pith balls suspended in front of the dial, to indicate when the signal should be read. The illustration below is of a portion of Ronalds's underground cable and protecting trough.



6 ***Ronalds's electrostatic telegraph erected in the garden of his house at the east end of the Upper Mall, Hammersmith, in 1816***
The illustration shows Ronalds's own drawing of a continuous overhead line, 8 miles in length, run to and fro between frames mounted 60 ft apart.

structed and described in the following words: 'A trench was dug in the garden 525 feet in length and 4 feet deep; in this was laid a trough of wood 2 inches square, well lined on the inside and out with pitch, and within this trough, thick glass tubes were placed, through which the wire ran. Joints between successive lengths of glass tubing were made with soft wax to permit expansion and the trough was covered with wood strips screwed down whilst the pitch was hot.'

The following quotation is from the account of the subsequent history given in his memoir[7] by Mr. A. J. Frost, first librarian of The Institution.

'He [Ronalds] decided upon bringing it to the notice of the Government. This he did on the 11th of July, 1816, in a letter addressed to Lord Melville, the First Lord of the Admiralty, as follows:

Mr. Ronalds presents his respectful compliments to Lord Melville, and takes the liberty of soliciting his lordship's attention to a mode of conveying telegraphic intelligence with great rapidity, accuracy and certainty in all states of the atmosphere, either at night or in the day, and at small expense, which has occurred to him whilst pursuing some electrical experiments. Having been at some pains to ascertain the *practicability* of the scheme, it appears to Mr. Ronalds, and to a few gentlemen by whom it has been examined, to possess several important advantages over any species of telegraphic hitherto invented, and he would be much gratified by an opportunity of demonstrating those advantages to Lord Melville by an experiment which he has no doubt would be deemed decisive, if it should be perfectly agreeable and consistent with his lordship's engagements to honour Mr. Ronalds with a call; or he would be very happy to explain more particularly the nature of the contrivance if Lord Melville could conveniently oblige him by appointing an interview. Upper Mall, Hammersmith.

'Shortly afterwards Mr. Ronalds received the following in reply:

Admiralty, July 29th 1816.

Sir,

I am desired by Lord Melville to acknowledge the receipt of your letter of the 11th instant. His Lordship has left town for some weeks, but he has requested me to see you on the subject of your discovery if you desire it.

I am, Sir,
Your most obedient, humble servant,
R. N. Hay.

'Mr. Ronalds replied that he did desire an interview, but before the nature of the invention had been made known except to Lord Henniker, Dr. Rees, Mr. Brande, and a few personal friends, he received the following laconic and curious communication from Mr. Barrow (afterwards Sir John Barrow), the Secretary of the Admiralty. "Mr. Barrow presents his compliments to Mr. Ronalds, and acquaints him with

reference to his note of the 3rd instant, that telegraphs of any kind are now wholly unnecessary; and that no other than the one now in use will be adopted. Admiralty Office, 5th August, 1816." '

Mr. Frost adds satirically that Sir John Barrow was the author of the article entitled 'Telegraph' in the seventh edition of the *Encyclopaedia Britannica*.

The papers referred to are now preserved in the Ronalds Library in the possession of The Institution.

Some Early Voltaic Systems

The development of the primary battery or voltaic cell, based on the work of Professors Galvani and Volta, has been discussed in the first and second articles in this series. Workable batteries based on Volta's pile were in use in laboratories from the year 1800, the year in which Nicholson and Carlisle demonstrated the electrolysis of water with the aid of a voltaic cell. It is not surprising, therefore, that Salvá, whose work is described above, and Samuel Thomas von Sömmering (1755–1830), in seeking to harness the much more convenient voltaic electricity for the purpose of the telegraph, years before the discovery of electromagnetism, should have looked to the phenomenon of electrolysis as a means of indicating the passage of an electric current.

In Sömmering's apparatus, signals were based upon 25 letters of the German alphabet and 10 numerals, making a total of 35 symbols, for each of which a separate wire was used. At the transmitting end the wires terminated in a row of sockets and at the receiving end were brought up through the base of a glass reservoir in the form of 35 gold electrodes, suitably grouped and labelled.

In order to send a message, wires from the battery were inserted in selected plugs, forming a two-letter combination, and at the distant end hydrogen and oxygen were generated in the electrolyte, becoming apparent by a stream of bubbles rising from each of the selected electrodes.

The evolution of hydrogen was noticeably greater than that of the oxygen, and it was part of Sömmering's system to telegraph in two-letter groups, taking as the first letter that corresponding to the electrode generating the hydrogen bubbles. Sömmering's paper[9] gives full details of his system, which makes use of the fact that the polarity of a selected pair of electrodes may be changed as desired and the meaning of the 'syllable' thereby reversed.

The cable used by Sömmering consisted of brass or copper wires insulated with a coating of lacquer, covered with silk and bound together to form a cable with an impregnated ribbon added for further protection.

Dr. Sömmering, who was a distinguished member of the medical profession, appears to have distributed several working models of his telegraph, which reached Paris, Vienna and probably St. Petersburg. It was shown to leading statesmen and in Court circles, but there is no indication that it ever received more than small-scale trials.

Sömmering's experiments and the publicity associated with them did much to increase the public interest in telegraphy, as well as attracting the attention of other inventors. Thus in 1811 J. S. C. Schweigger (1779–1857), of Halle in Germany, pointed out that a fundamental objection to the Sömmering system lay in the number of wires required. He claimed to be able to achieve similar results with two wires only (and earth return), using two piles or batteries of differing power by employing an improved code and timing the gas discharges.

Schweigger is best remembered for his invention of the galvanometer, or galvano-magnetic multiplier or indicator, as it was first called, a description of which appeared in Germany in November, 1820. This is not to be confused with the twin needle, or astatic, instrument invented by Ampère in 1821.

Hitherto the telegraphs invented for use with voltaic batteries were of the electrochemical type, but about 1820, the Marquis de Laplace (1749–1827) suggested that magnetic needles could, for telegraphic purposes, be substituted for the voltameter cells, around which earlier systems had been developed. The suggestion was immediately taken up by Ampère and others, but as yet it was considered necessary to employ as many pairs of line wires and magnetic needles as there were letters in the alphabet and other symbols to be transmitted. Baron P. L. Schilling (1786–1837) of Kannstadt first became interested in telegraphy when in 1810 he witnessed

7 *Telegraph of Dr. S. T. von Sömmering, about 1809*
The illustration shows the cable of 35 wires, voltaic column and glass receptacle containing the electrolyte at the receiving end.

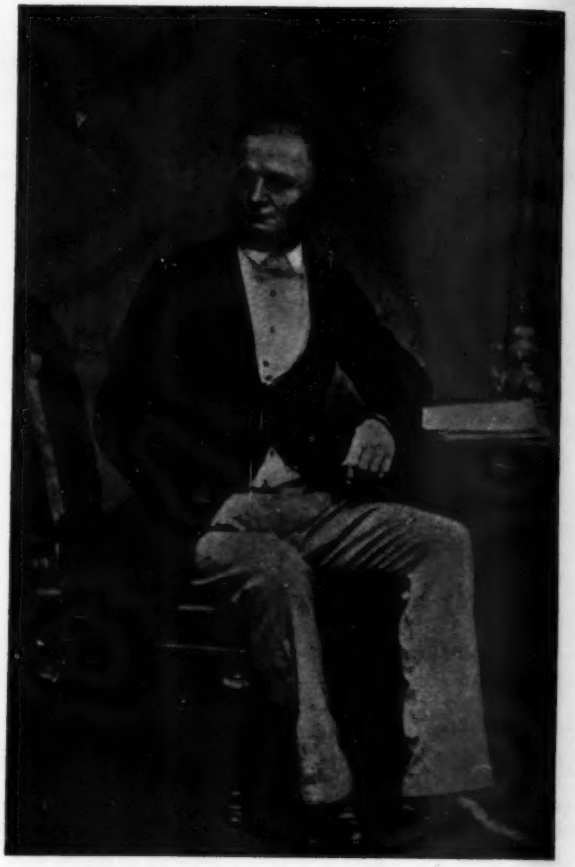
several demonstrations at Sömmering's house at Munich, and was responsible for what was almost certainly the first effective needle telegraph.

Schilling, a member of the Russian diplomatic corps, spent many years in Germany and during his residence produced several electromagnetic telegraphs. His principal object was to obtain support of the Czar, which he succeeded in doing only a year before his death.

It is not easy to fix a precise date for the completion of Schilling's first instruments, for he does not seem to have followed the customary practice of communicating particulars of his invention to one of the learned societies, but 1825 has been suggested as the most probable.

Schilling caused his needle to swing to the right or left of its neutral position, according to the direction of flow of the current impulses in the circuit, and employed as a method of damping the oscillations of the needle a light plate attached to the needle suspension system, and in contact with a small bath of mercury. For the purpose of his telegraph, Schilling adopted a two-symbol code of the type which had previously been used for many years with some optical and other systems of communication and thus anticipated the telegraphic code, usually credited to Samuel Morse, to which further reference will be made.

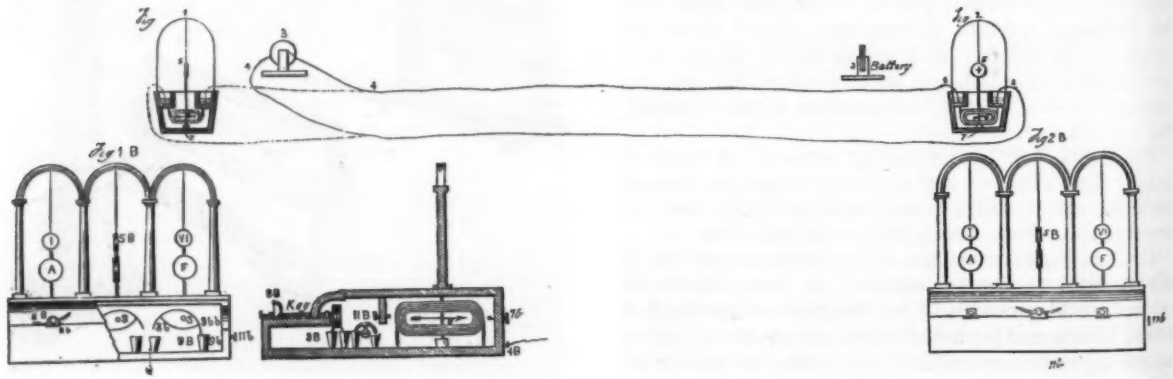
Baron Schilling sent copies of his instruments to friends in different parts of Europe, and a working pair came into the possession of Professor Muncke of Heidelberg in 1835. It is on record that the Professor gave regular demonstrations to his students, and it was in this manner that Sir William Fothergill Cooke (1806–1879) first became acquainted with the electromagnetic needle telegraph on the 6th March, 1836. At this period, Cooke was studying anatomy at Heidelberg, having recently been invalided home from the Indian Army, and he was so taken with the idea that he started to make an apparatus of his own which, as might be expected, did not differ appreciably from the prototype. Convinced that he could introduce sufficient improvements to ensure commercial success, Cooke decided to return to England. At this point, it may be questioned why a country such as our own, which had contributed so much towards the development of electrical science, should have been so slow in following up the suggestions of Laplace and



8 *Sir William Fothergill Cooke (1806–1879)*

9 *Cooke's diagrams of early telegraphic instruments*

The upper pair of instruments comprise two single-needle galvanometers 5 with battery 3 and two line wires 4, as used and demonstrated by Professor Muncke of Heidelberg. They were probably made by Baron Schilling about 1835. The lower Figures show Cooke's first galvanometer telegraph instruments, which used six interconnecting wires.



Ampère, and the experiments of Schilling, which must have been known here for at least a decade. The answer may perhaps be found in the fact that both in this country and in the United States prominent electricians had expressed the opinion that the voltaic telegraph was fundamentally impracticable, by virtue of the effect of the resistance of the wires. Peter Barlow, F.R.S. (1776–1827), sometime professor at the Royal Military Academy at Woolwich, was well known for his work in the sphere of electricity and magnetism, and in 1824 he made an experiment to determine whether the idea of a 'galvanic needle telegraph' was practicable. He published his findings in the *Edinburgh Philosophical Journal*[10] in the following terms:

> It had been said that the electric fluid from a common electric battery had been transmitted through a wire four miles in length without any sensible diminution of effect, and, to every appearance, instantaneously; and if this should be found to be the case with the galvanic circuit, then no question could be entertained of the practicability and utility of the suggestion above adverted to. I was therefore induced to make the trial; but I found such a sensible diminution with only 200ft of wire, as at once to convince me of the impracticability of the scheme.

It will be understood that Barlow's 'common electric battery' was a charged Leyden jar.

Soon after his arrival in London on the 22nd April, 1836, Cooke experimented over greater lengths of line than hitherto and encountered the difficulty which Barlow had described, owing to which the electromagnets which he employed to release the clockwork operating his alarm failed to release. The alarm was considered to be an essential part of the telegraph, and it was in these circumstances that Cooke, on the advice of others, sought out the assistance of Professor Charles Wheatstone, F.R.S. (1802–1875), then occupying the chair of Experimental Physics at King's College in London.

The first meeting between the two men took place on the 27th February, 1837, and as a result they agreed to form a partnership for the purpose of exploiting the telegraphs. Their joint patent, No. 7390 of the 12th June, 1837, was the first telegraph patent granted anywhere in the world and in it are to be found descriptions of the following:

(i) A five-needle telegraph with five finger keys on which the symbols are indicated by the simultaneous deflection of two of the needles, the required letter being found on the dial at the point where the two converge.
(ii) A four-needle telegraph on the same principle.
(iii) Methods of insulating and supporting the wires, which consisted of placing them in a resinous cement in channels in the rails of post and rail fences, or in various shaped tubes or troughs, the wires being previously covered with cotton and varnished.
(iv) A method of deflecting telegraph magnetic needles by electromagnets.
(v) A method of sounding alarums in distant places: the detent of a clockwork mechanism is removed by an electromagnet.
(vi) Sounding alarums in distant places by the aid of an additional battery—a battery devoted solely to working the alarum, and not belonging to the line circuit, has its local circuit completed by the electric current from the distant battery. For this purpose the line circuit deflects a needle on whose axis a forked wire is mounted, which completes the local circuit by dipping into mercury cup.

Cooke and Wheatstone were not the only promoters of telegraph projects in London, for Edward Davy (1806–1885) had independently been working along similar lines since 1836. The late J. J. Fahie, who was in touch with Davy and had access to family papers after his death, has expressed the opinion that to Davy belongs the credit for the discovery of the relay system, as applied to telegraphy. The work of these pioneers will further be discussed in greater detail in the next article.

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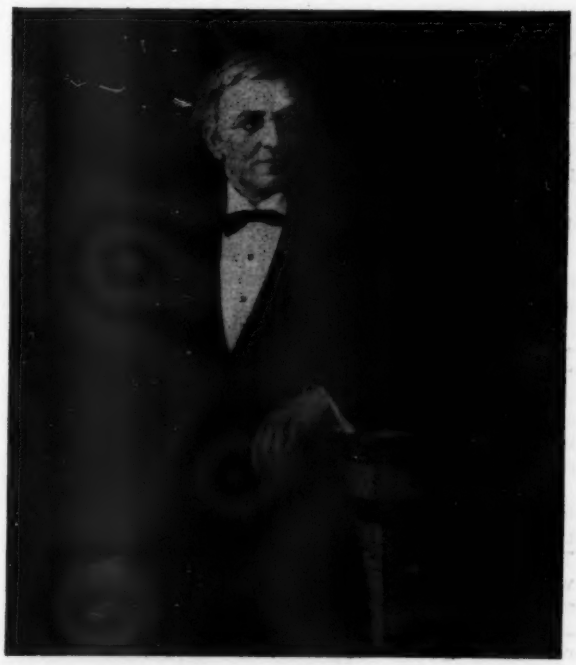
10 *Sir Charles Wheatstone, F.R.S. (1802–1875)*
From the portrait after Sir William Llewellyn, R.A., in the possession of The Institution.



Development and Research in Electrical Machine Design

L. D. ANSCOMBE, M.A., MEMBER

The history of electrical machines is one of continuous progress. Although the basic principles have long been established the art of machine design is far from routine. The advent of new materials, the discovery of new techniques and the need to overcome day-to-day problems call for the greatest ingenuity and the soundest judgment. Modern machines are thus superior to their predecessors in performance, reliability, versatility and elegance, and the evolution of still better ones continues steadily.

The author has prepared this article from his Chairman's Address to the Rugby Sub-Centre, delivered on the 11th October, 1955.

Introduction

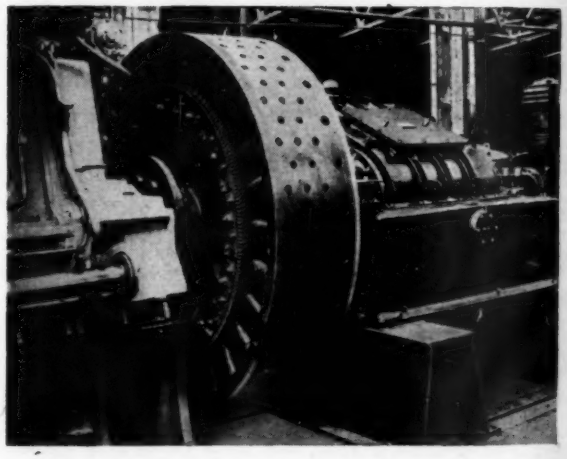
It is sometimes thought that the electrical machinery side of engineering is now so well established that there can be few opportunities left for further investigation and development. In fact this is by no means the case, and there is ample scope for the engineer with an inquiring mind in this field. The existence of an extensive background of technical papers and books on design may be misleading. Superficially, this literature appears to reveal almost all there is to know about electrical machinery; yet the engineer with a critical outlook soon discovers how often a well-known convention or approximation has glossed over real uncertainty as to the true problem involved. The latest techniques of analysis and measurement provide the means for a re-examination of many established design practices and for the successful tackling of the new problems which continually arise.

What is Development?

Development is a very broad term. It can include any aspect of an engineer's work which extends the knowledge and skill of himself, his department and the profession as a whole. But its main purpose must be to provide him and his immediate colleagues with the means to increase the scope of their work either by improving their product so as to secure more business or by enabling them to enter new fields. The examples I shall draw upon to illustrate my remarks are of local origin but I hope they are reasonably typical of the rotating-machine branch of the profession.

First I should like to point out a fundamental difference between the problems which face the machine designer and those in some other branches of electrical engineering. The electrical machine is built up into a complex single entity which cannot be easily broken down into component parts, each capable of separate verification and adjustment. The completed equipment usually yields only limited test data embodying the simultaneous effect of several variables. Therefore, in comparison with, say, the control-system designer, who can arrange adequate means of adjustment and test for many components in the sequence of his system, the designer is at a disadvantage in checking his analysis.

An extreme example of this difficulty occurs with the electromagnetic slip coupling used (in some ship-propulsion equipments) between Diesel engines and reduction gears as a means both of damping engine-torque pulsations and of providing reversing control (Fig. 1). Both inner and outer



1 *1520 h.p. 300 r.p.m. electromagnetic slip coupling on test with Diesel engine and gearbox*

members of this coupling are overhung from shafting and rotate, the torque being produced by the interaction between a multipolar field system on one member and a short-circuited winding, usually double squirrel-cage, on the other. Solid poles or pole-face damping windings are a necessary feature as well. The machine resembles a variable-frequency short-circuited alternator, but it exhibits damping characteristics which vary with the frequency of the harmonic torque applied. It has also some unexpected elastic properties. To test this device over its operating range a very rigid mechanical assembly able to withstand unbalanced magnetic pull is required, together with facilities for transmitting full power through the coupling, but even if these are available only an indication of the success of the design as a whole can be obtained. The designer can check the slip-torque characteristics at various values of excitation and also obtain data on the heating of the windings, but it is extremely difficult for him to discover the causes of discrepancies that appear. Nor can he check the true effectiveness of the coupling when it is placed in the complex torsional system of which it is the king-pin.

Even the well-known and highly developed synchronous motor presents similar difficulties. Because the machine has salient poles, its performance can be fully investigated only by two-axis theory using an equivalent network for each axis. In the direct-axis network there is a family of coupled rotor circuits each one representing a pair of bars in the pole-face winding, together with a circuit for the field winding. Induced currents in any solid part of the rotor magnetic circuit have also to be considered in this network. The quadrature-axis network is simplified by the absence of a field winding and yet it is made more complex by the permeance variation of the interpolar space.

By means of Park's equations it is possible to establish the networks and to calculate the starting-torque characteristics of the machine, given the self and mutual coefficients of each component circuit, but the designer still has the important tasks of devising these practical coefficients, of accounting for the inevitable discrepancies which arise between theory and practice and of accounting for the effects of saturation. He finds himself wishing he could wind the rotor of the machine stage by stage, assembling and testing by impedance and acceleration as each winding or pair of bars is fitted in turn.

A notable effort recently has been the building of an experimental machine for analysis in this way. Valuable information has been obtained, but many variables could still not be isolated because of the limitations of using a fixed number of poles and pole-face slots. For the rest of the confirmation of his theories the designer must rely on a painstaking analysis of the final result of his work on a series of production machines, each of which wraps up the effect of all his variables in virtually a single answer.

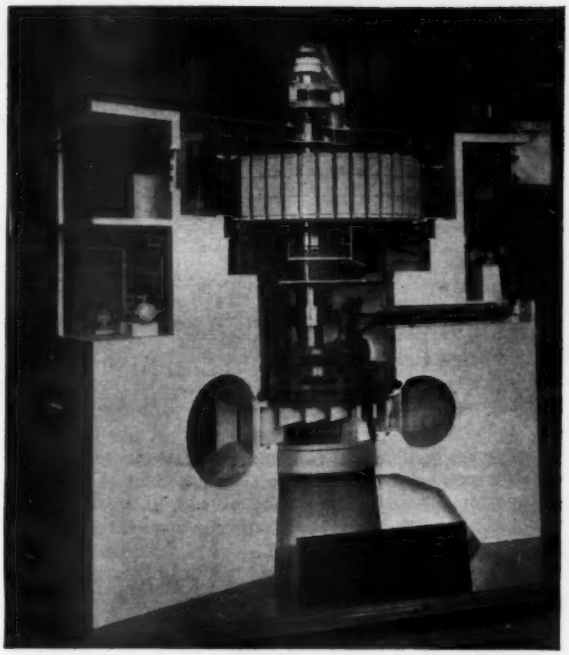
Short-Term Development

Much development work takes the form of an investigation to meet an immediate need. These short-term investigations are naturally self-starting. Some arise directly from demands of potential customers, others are stimulated by sheer necessity to meet unforeseen difficulties.

Development of this kind is not likely to be of a highly theoretical nature requiring extensive experimental verification before it can be applied, but it must, on the basis of past experience, provide a reliable practical answer with the least delay. Only in exceptional circumstances is there time for model or prototype equipment to be made, although this is more likely to be possible where small machines are concerned.

For example, the rapid practical and theoretical development of the inductor alternator during the Second World War was aided both by the exceptional importance attached to the work at the time and by the relatively small physical size of the machines then involved.

In a large-machine design department a very stimulating form of investigation, of the kind which calls for rapid judgment based on previous experience, arises frequently when a tender has to be prepared for a large unit of new construction or of a size not previously built by the organization. A large water-wheel alternator is perhaps the extreme example of such a 'tailor-made' electrical machine. Its design is affected greatly by hydraulic conditions which determine its running speed, runaway speed and stored energy. Power-system conditions affect the reactances and the excitation response, and site layout affects the arrangement of its structure and the placing of its auxiliaries. In a short space of time a small group of engineers are expected to resolve these often conflicting demands in the best possible compromise which they hope will secure an order and which they themselves must be able to achieve should an order result.



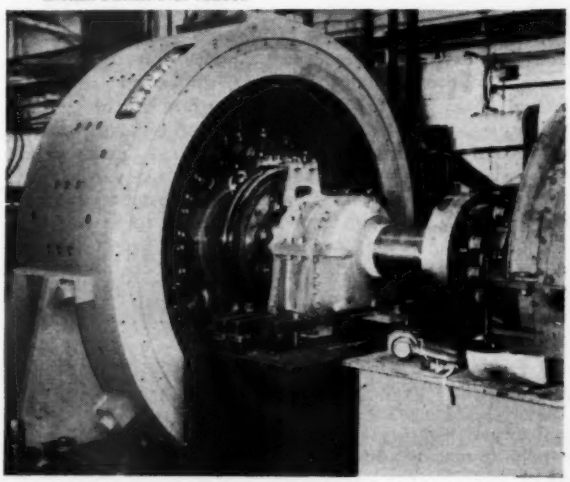
2 *Model of 44 400 kVA 136 r.p.m. water-wheel alternator for Roxburgh, New Zealand*

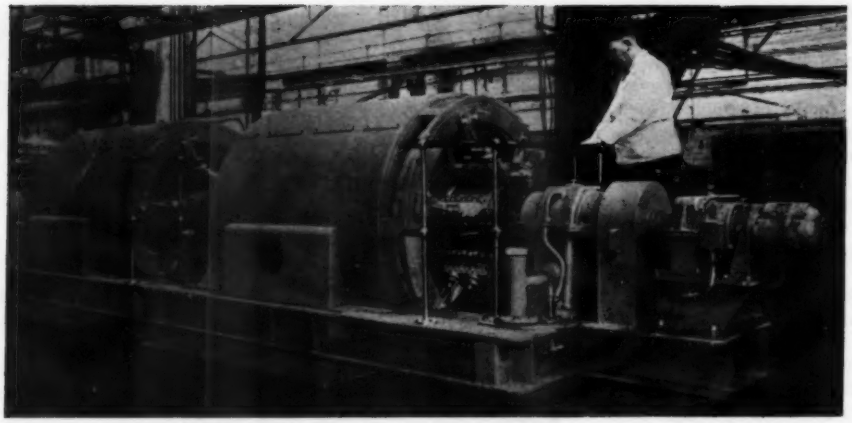
A scale model (Fig. 2) of one of the 44 400 kVA 136 r.p.m. hydro-electric generators built for Roxburgh power station, New Zealand, emphasizes the mechanical problems which must be solved in such cases, and the close liaison which must be established with the civil engineers.

An unusual instance of 'tailor-making' is a development of

3 *630 h.p. 500 kW 300 r.p.m. slip-coupling/alternator on test with locked outer member*

British Patent No. 702861





4 *900 h.p. 233/955 r.p.m. double-unit low-inertia reel motor*

the slip coupling already described, but in the form of a coupling/alternator (Fig. 3). This machine was evolved for vessels (such as cement carriers) which require electrical power for cargo handling comparable with the power needed for propulsion. The electrical machine can act either as a slip coupling connecting the Diesel engine to the propeller shaft, or (with the shaft member locked at standstill) as a generator to supply motors for the discharge of cargo.

Another example of the effect of a new demand has been the recent important change in the design of large d.c. motors for continuous-strip rolling mills. In the modern high-speed mill, rapid acceleration and accuracy of control depend largely upon obtaining very low inertia in the driving motors. The conventional conception of the d.c. machine with a limited core length aimed at ease of commutation and ventilation goes by the board when one encounters machines such as the modern reel motor shown in Fig. 4, each unit of which has a core length much greater than the diameter of the armature.

Long-Term Research and Development

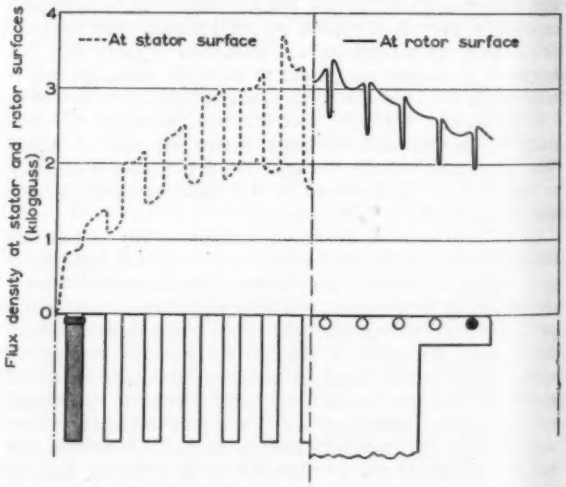
I now come to the most important aspect of the work of a machine-design team—the initiation and carrying out of long-term investigations. These investigations are no longer under the spur of the need to find an immediate answer, but are directed at improving the type of machine and at anticipating future demands. Much of the work can be rightly called applied research.

This work must be undertaken in cold blood, so to speak, and the difficulty most engineers experience in freeing themselves from ever-recurring day-to-day duties can handicap it severely unless special arrangements are made. Many individuals who are most fitted to pursue such investigations are often least able to devote time to them, and those who are segregated for the purpose may lack the necessary experience.

The establishment of a separate development section in a machine-design department is desirable; yet to be successful it must be staffed with men who have had design experience and are prepared to work closely with other engineers in the production groups who are themselves taking a forward view and following their own particular lines of investigation alongside regular production work.

Theoretical Work. Long-term development can be roughly divided into two classes—the mainly theoretical and the mainly practical. Every organization hopes to have on its staff a few individuals who are able and willing to make fundamental studies in machine theory, which may have no very direct or immediate effect on design work. The application of tensor analysis to machines and the continued study of advanced synchronous-machine theory are examples of work of this nature which is gradually bearing fruit in the design office.

There is scope also for theoretical treatment of many design problems which have hitherto been solved largely by intuitive methods. This is now increasingly important because the art of machine design has entered the stage at which refinements are economically justified, and, furthermore, design with a large factor of safety (or perhaps of ignorance) no longer obtains much business. Much of the work of the late Dr. F. W. Carter helped in this way. We owe to him the fundamental mathematical analysis of air-gap flux distribution which has made possible, among other things, the scientific design of the inductor alternators to which I have already referred. In the same category is the important work on flux penetration into solid magnetic materials. By means of a new approach to the subject, fresh light has been thrown on the design of machines which make practical use of currents induced in solid metal, such as the eddy-current coupling and the solid-pole self-starting synchronous motor. Additional benefits have also been gained from greater accuracy in the calculation of losses arising from unwanted eddy currents



5 *Air-gap flux measurements in salient-pole machine by germanium probe*

(such as high-frequency losses caused by the inductor action of winding slots) and in the study of parasitic losses in pole-face windings and of harmonics in voltage waveforms.

For the practical measurement and verification of the particular flux pattern which is the key to each of these related phenomena we now have a new instrument in the form of the germanium probe or gaussmeter. This probe enables any local value of air-gap flux density to be measured under static conditions (Fig. 5). Nevertheless, the modern miniature search coil is still the most important research tool available for this work since it can also be used while the machine is running on test, thus recording the flux conditions which will exist when the machine is in normal service.

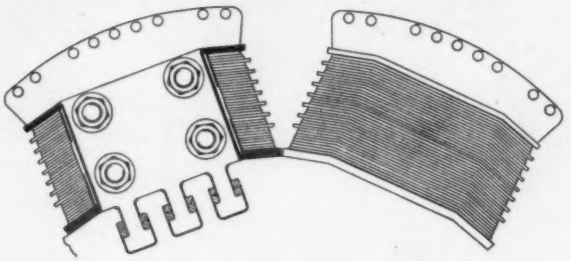
Practical Development. Many investigations spring from early recognition of probable new operating conditions for the apparatus, or from awareness of deficiencies in current practice. Others arise from the development of new materials and new manufacturing techniques.

The invention and development of the Pollock commutator is an interesting example. By the dovetailing of each segment along its full length into a welded assembly of steel anchor bars one can dispense with the conventional V-rings and build a high-speed commutator without shrink rings. Details of this construction are quite well known, and it should now be said that the results of service experience, gained with the large number of such commutators already built, have been excellent. This is a fully established alternative to the conventional commutator.

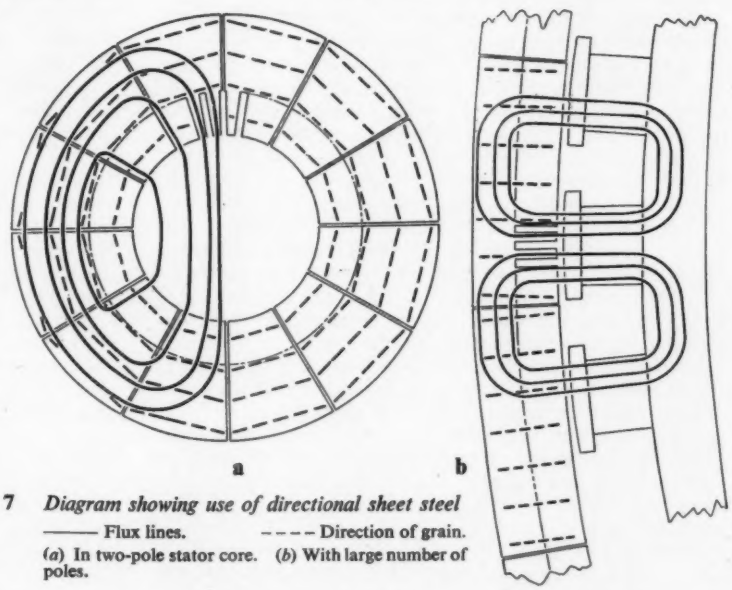
Another development involving an improved method of holding active copper against centrifugal force is the 'canted' field coil. The increasing attention now being paid to economy in crane capacity and station structure at hydro-electric power stations has led designers to devise methods of supporting the field coils of salient-pole machines in such a way that the whole pole can be inserted or withdrawn axially, without the need to lift the rotor. The familiar V-block or bracket bolted to the spider is mechanically straightforward and effective, but its fixing screws can be removed only radially. Dovetailed or keyed versions have been devised to allow of axial withdrawal but in achieving this feature one loses some rigidity of support to the coil. A good solution to the problem of withdrawal is the strap-type support which embraces each separate coil side, and is tightened by external screws over an insulating former. The wound and braced pole is then self-contained.

All these types offer appreciable obstruction to axial flow of air between the poles of the machine, and so one looks for a means of making the coil self-supporting against the component of centrifugal force perpendicular to the pole side, without making use of the interpolar space at all. The important recent development of fabricated-strip field coils has made such a solution possible. If the end limbs of each rectangular turn are bent downwards and brazed to the longitudinal side strips, the side limbs can be inclined at such an angle that the bursting force is transmitted up the coil to the pole shoe. The shoe must, therefore, be specially shaped to match the angle of the copper (Fig. 6).

New Materials. Some of the most important opportunities for development lie in a quick appreciation of the value of new materials. Although, of course, little use can be made in electrical machines of the wide range of special steels recently developed for high-temperature duty, the new light alloys have their significance in the field of airborne electrical equipment. It is, however, with improvements in magnetic sheet steel that the designer is mainly concerned, since this constitutes the main flux-carrying material of his machine. The striking reductions in the specific loss of hot-rolled sheet steel that has been recently developed are benefiting both machines and transformers, but the machine designer has also to study the permeability, surface finish, and ductility of the material. Theoretically the choice of material is a matter of economics, determined by a comparison between the extra cost of the material and the annual saving expected from the reduced loss. Commercial considerations and the lack of exact information often make the choice a difficult one, but the use of high-silicon steel is now usually justified for continuously running motors and much generating plant.

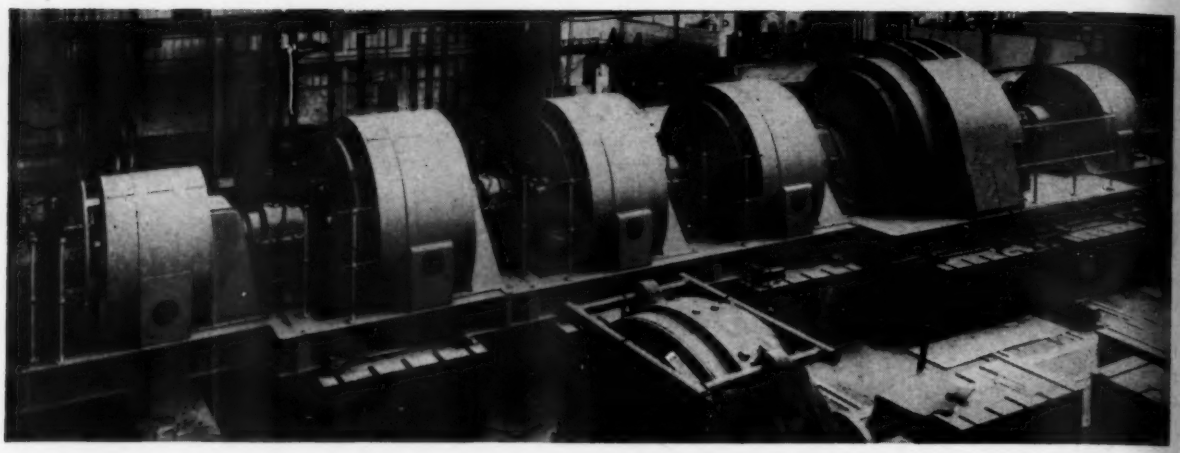


6 *Diagram of 'canted' fabricated field coil*
British Patent No. 622083.



7 *Diagram showing use of directional sheet steel*
——— Flux lines. – – – – Direction of grain.
(*a*) In two-pole stator core. (*b*) With large number of poles.

The use of cold-rolled directional sheet steel has possibilities in rotating machines as well as in transformers. The usefulness of this steel is most appreciable in the two-pole machine, where the major loss occurs in the annular portion of the core



8 *Motor-generator set with 8 880 h.p. synchronous motor*

external to the slotted portion. Here the direction of flux is mainly tangential, and by cutting segments from the sheet steel in such a way that the preferred direction is also tangential a substantial reduction in the loss can be obtained, as in Fig. 7(*a*). The benefit of the arrangement falls off rapidly as the number of poles increases, but advantage can be taken of the radial placing of the preferred direction to relieve tooth losses in low-speed machines, as in Fig. 7(*b*).

Unfortunately the high cost in this country of cold-rolled directional sheet steel as compared with the best hot-rolled material normally renders its use uneconomic at present. Full-scale development work has shown that the reduction in core loss, accompanied by the saving in field magnetomotive force (in ampere-turns) resulting from the better permeability of the preferred direction, should cause its wide adoption, at least in high-speed machines, if the cost can be reduced.

Although further improvements in magnetic sheet materials are not likely to be so rapid in future, the possibilities in the field of insulation are immense. The process of replacing many natural organic materials and varnishes by synthetic products is already well advanced. The established polyvinyl acetal covering for wires used in combination with oil-modified synthetic resin-varnish was the forerunner of a series of synthetic materials, the importance of which is now leading to the introduction of additional insulation classifications. Woven glass-fibre insulation has also greatly improved the mechanical properties of coils and contributed to longer life at operating temperature, besides acting as a carrier for new varnishes such as silicones.

The work of applying these new insulating materials to a product which should have an expected life of twenty or thirty years is of major significance to the designer. The most important wearing parts of the electrical machine are its windings. Unlike brushes and bearing liners they are not easily replaceable, but yet they age continuously with service and therefore cannot have the indefinitely long life of most of the mechanical parts. Much experimental work with material samples and built-up coils has been done since the war, and the modern winding is immensely superior to its predecessors.

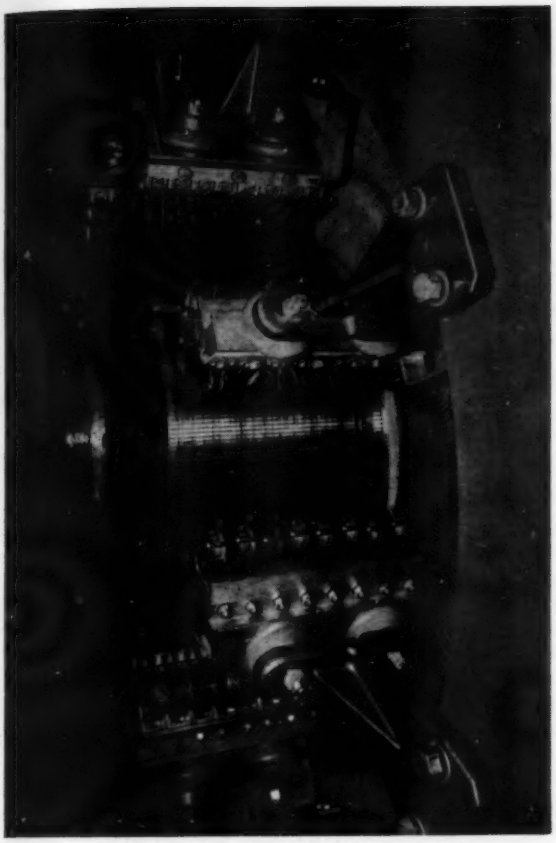
A new life-test equipment to give repeated thermal cycles to full-scale insulated conductors is now available and this should enable engineers to reproduce in a short time the differential effects of heating and cooling a high-voltage coil during many years of normal service. By comparison between established and new insulators it is expected that the new materials can be safely introduced without the need for extensive service trials. Although such apparatus enables only one of several factors influencing insulation life to be tested, its use by the development engineer in conjunction with other tests should prove of great value. Attempts to devise a comprehensive short-time life test adequately introducing all the important factors are being made in the United States and Canada, but it is doubtful if such a test can be as reliable as the combination of experience and experimental data by which insulations are judged at present.

External Appearance of Machines. Another aspect of design, which is in the nature of development, concerns the appearance of the product. The term 'appearance design' is perhaps hardly applicable to industrial machinery or power equipment since it suggests an excessive preoccupation with externals, more appropriate to the merchandizing business. Yet it is often possible and most desirable that capital goods should be aesthetically pleasing, provided that accessibility is maintained and unnecessary cost avoided.

The d.c. machine lends itself most readily to improvement in this way because it lacks the smooth and simple enclosure naturally provided in most a.c. machines by the cooling-air structure and frame which surrounds the stator core. The magnet frame of the d.c. machine with its bolted poles, flanged joints and massive feet characteristically displays many excrescences, and of course the commutator itself must normally be exposed for cooling and accessibility of brush gear.

Both appearance and ease of cleaning have been greatly helped recently in large motor-generator sets by the recessing and covering of the pole bolts, redesign of frame joints and enclosure of the frame feet (Fig. 8). A close view of the brushgear of one of these machines (Fig. 9) also shows the advantage of considering appearance in the design of die castings for brush boxes and brush arms.

Losses in Machines. An important field of long-term development, to which much attention has been given, is that of machine efficiency. There is still a need for more accurate prediction of losses and careful design for their reduction other than by merely using better materials. The measured open-circuit core loss of a given machine presents one of those composite answers to a complex problem which,



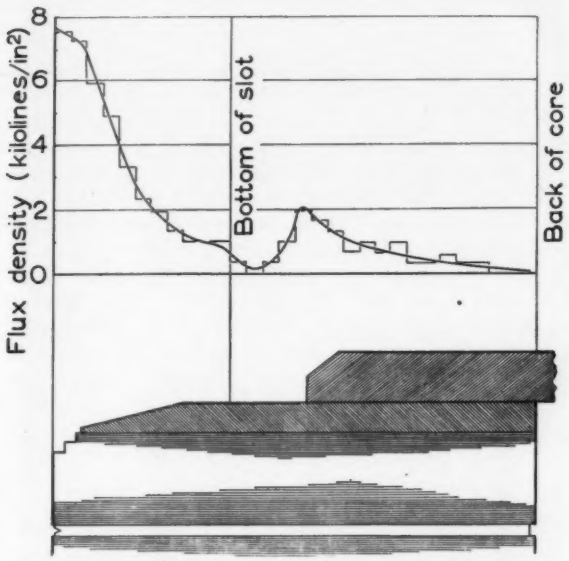
9 *New design of d.c. brushgear*
British Patent No. 719847.

as already indicated, so often faces the designer. The conventional assessment of core loss makes use of certain empirical constants which cover up much ignorance of the true loss, even in the magnetic sheet of the core and teeth portions of the armature, where one would expect the problem to be quite straightforward.

Now that the pole-face component of core loss is satisfactorily accounted for, it is likely that much of the uncertainty still remaining can be attributed to faulty assessment of the loss due to components of magnetic flux which pass from the poles to the armature, or vice versa, in an axial direction. Flux entering the core perpendicularly to the laminations will set up comparatively heavy eddy-current losses either in the core itself or in the structure supporting and clamping it. Much full-scale experimental work has been carried out with stepped cores, non-magnetic end structures and shielding devices, but much still remains to be done.

One method of attacking the end-loss problem in the design department is by the use of the conducting-paper flux plot. Imperfections in the paper as yet available are a disadvantage, but the simplicity and rapidity with which the iron boundaries can be painted on this paper make this technique suitable for two-dimensional work with electromagnetic fields rather than the use of the electrolytic-tank analogy which finds its main application in electrostatic problems. Fig. 10 shows the results of a conducting-paper flux plot to determine the axial flux density on the surface of the end structure at the centre line of a pole on no-load.

An important investigation is also under way using a model alternator in which measurements can be made with slotted and unslotted cores of variable length and with other modifications. It is hoped that by a painstaking analysis of the results



10 *Axial flux distribution at end of stator core using non-magnetic clamping fingers obtained by conducting-paper flux plot*

it will be possible at last to reduce the factor of ignorance which designers must still apply to their calculations before guarantees can be made. Associated with this problem, but even more complex, is the so-called 'load loss' of the synchronous machine, which arises mainly from harmonic and stray fluxes of armature reaction when current is carried by the windings. Only by such an experimental method can significant progress be made towards the satisfactory solution of these problems.

Conclusion

The possibilities of long-term research and development in electrical machines are still in fact endless, and I am conscious of many important omissions in this brief survey. In particular, space does not permit me to refer to mechanical problems or to the problems of heat flow and ventilation, which are vital enough in all types but now particularly so in large hydrogen-cooled turbo-alternators. I hope, however, that the examples which I have given are enough to show something of the extent of the work ahead.

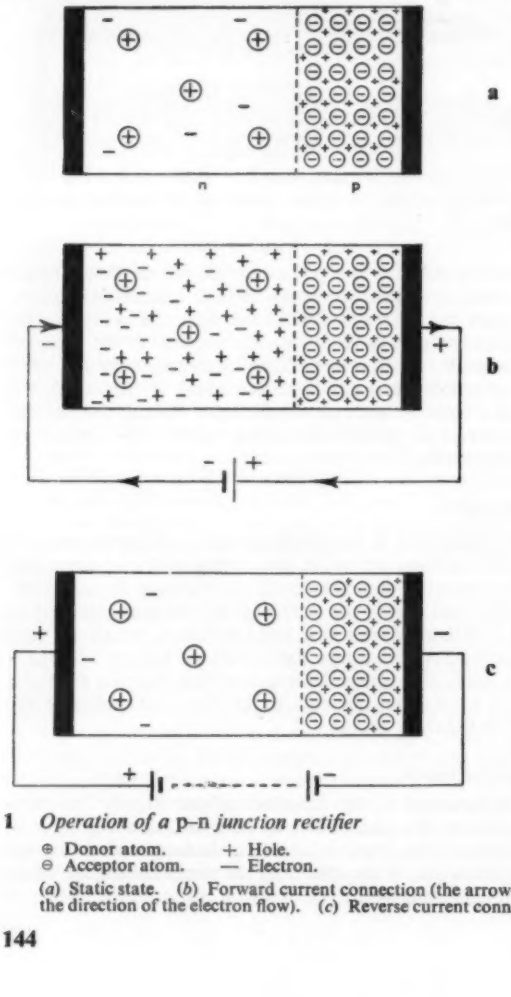
Acknowledgments

I am indebted to the Directors of the British Thomson-Houston Co. for permission to refer to these examples of development and research, and I particularly wish to express my appreciation of the efforts of the many colleagues whose work I have described.

Fused-Junction Rectifiers

This article is based on a paper entitled 'Germanium and Silicon Power Rectifiers' by T. H. Kinman, M.B.E., Member, G. A. Carrick, M.A., R. G. Hibberd, B.Sc., Associate Member, and A. J. Blundell, Associate Member, all of whom are with the British Thomson-Houston Co. The paper, which excited great interest, was read by Mr. Kinman, and subsequently discussed at an Ordinary Meeting at Savoy Place on the 10th November, 1955.

THE extensive use of semi-conductors in electrical engineering has resulted in some remarkable innovations, but few of them are more impressive than the recent development of the germanium or silicon power rectifier, which works silently at an efficiency of 97% and occupies only a small fraction of the space taken by other convertors. The power rectifier uses a number of small rectifying cells connected in series or in parallel according to the current and voltage to be rectified, and designs may be drawn up to meet almost all requirements.



1 *Operation of a* p–n *junction rectifier*

⊕ Donor atom. + Hole.
⊖ Acceptor atom. — Electron.

(*a*) Static state. (*b*) Forward current connection (the arrows show the direction of the electron flow). (*c*) Reverse current connection.

An installation capable of handling 1 MW is already in service and still larger ones are under construction.

The new rectifier owes its performance to the unique properties of the *p-n* junction, a diagram of which is shown in Fig. 1(*a*), where the interface between the *p*- and *n*-type regions is represented by the broken line. When a potential difference is applied across the base contacts as in Fig. 1(*b*), holes flow through the junction and combine with the electrons—mainly at the base contact of the *n*-type region, according to the latest theory. Fresh electrons enter the *n*-region from the left and new holes are injected into the *p*-region from the right; the process is clearly continuous and a current flows. When the potential is reversed, however, as in Fig. 1(*c*), the electrons in the *n*-region are attracted to the left towards the positively charged base-plate, while, conversely, the holes are attracted towards the right. There is thus no flow of carriers through the junction and hence no current in the circuit. The movement of electrons and holes away from the junction leaves the positive donor impurities and the negative acceptor impurities without their respective balancing charges of electrons and holes, and so a potential difference is built up across the junction, exactly countering the impressed potential.

The reverse current is not quite zero, however, because at normal temperatures germanium, like most semi-conductors, exhibits some degree of *intrinsic* semi-conduction caused by thermal agitation of the electron structure, which gives rise to a small but steady supply of electron-hole pairs in the region of the junction.

Junctions can be made in a variety of ways but they fall broadly into three categories—grown, diffused and fused junctions. The first may be produced by treatment of the growing crystal, the second by diffusing the impurity into one face of the crystal and the third by fusing one impurity element into one surface, and the other impurity element into the opposite surface, of a thin slice of a single crystal. The last method is easiest and results in a rectifier capable of handling much higher current densities, and is the method described in this article.

Production of Pure Single Crystals

Since the electrical properties of a semi-conductor depend almost entirely upon the impurities and lattice

flaws present it is clearly imperative that the concentration and type of impurity should be carefully controlled; therefore the ideal starting material is a perfectly pure, single crystal, and any departure from perfection must be kept within very strict limits. The concentration of impurities which can be tolerated varies with the impurity, but must usually be not more than one part in a thousand million. Such purity would have been thought preposterous not many years ago and the fact that it is now possible to achieve it, not only in the laboratory but in the factory as well, is a major triumph of modern industry.

Chemically pure germanium dioxide, extracted from flue dusts, is available in ample supplies. The main impurity present is arsenic—unfortunately a particularly harmful one because its valency is higher than that of germanium, and it therefore acts as a donor impurity, i.e. each arsenic atom donates one mobile electron to the atomic lattice. The amount present after the chemical purification is 0·25 part per million, still 250 times greater than the tolerable concentration. The powder is reduced to metal by heating it in a long refractory crucible to 700° C in an atmosphere of hydrogen:

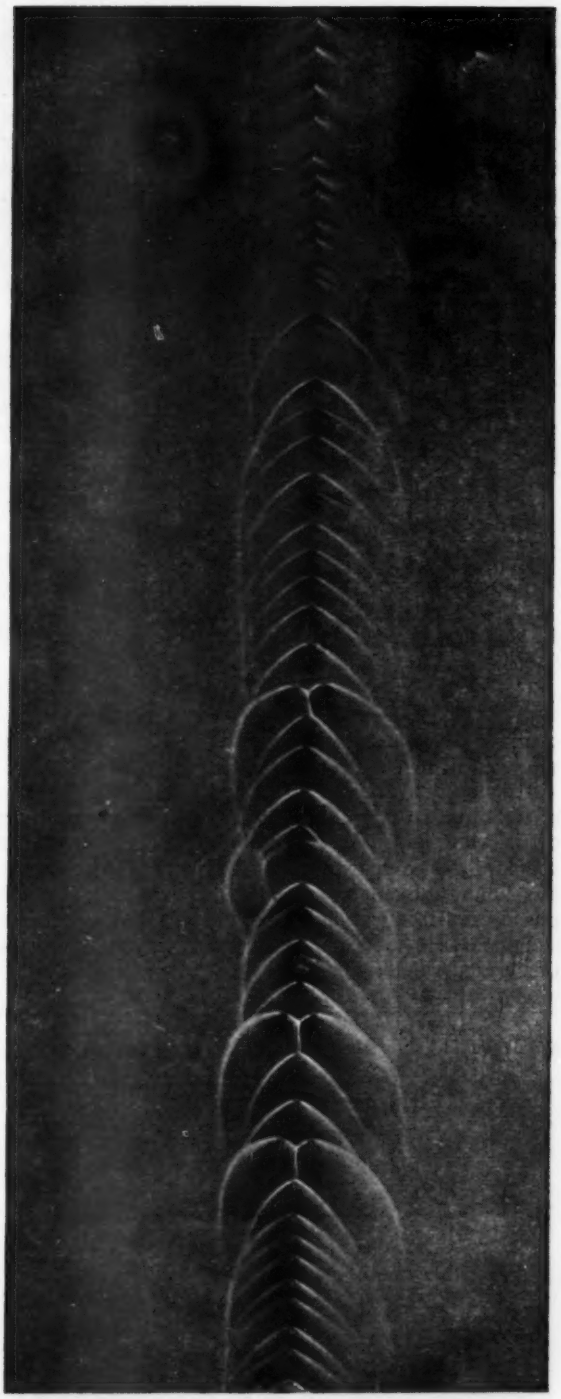
$$GeO_2 + 2H_2 = Ge + 2H_2O$$

When the reaction has been completed and the steam driven off, the metal is heated to well above its melting point and allowed to cool slowly and solidify in the form of an ingot, being annealed for two or three hours at 500° C before returning to room temperature.

The necessary purity is obtained by the elegant method of zone refining. The ingot, in a graphite boat, is pulled slowly through a number of high-frequency heating coils, which melt the germanium only locally. The impurities are more soluble in the liquid than in the solid phase, and concentrate in the molten zone. As the zone moves slowly along the length of the ingot, the impurities are swept to one end, which is subsequently cut off. When the metal has reached this stage of purity care has to be taken to ensure that it is not contaminated by the atmosphere in the ensuing processes.

The ingot is now pure but polycrystalline, and in order to form a single crystal the metal is melted in vacuum or a very pure inert gas, the temperature being carefully controlled at a few degrees above the melting point, and the furnace being protected from mechanical shock. If these conditions are not fulfilled the crystal may develop lattice flaws which would render it unfit for service. Subsequent examination by etching of selected sections reveals any such flaws, an example of which, the edge of a dislocation, is shown in Fig. 2. A germanium 'seed' crystal about half an inch in diameter, cut perpendicular to one crystal axis and rotated at 100 r.p.m., is lowered to the surface of the molten metal and slowly raised a few inches per hour. The germanium solidifies at the junction of the growing crystal and the melt, each atom falling into place in the regular crystal array. The rotation has been found to help in obtaining homogeneity.

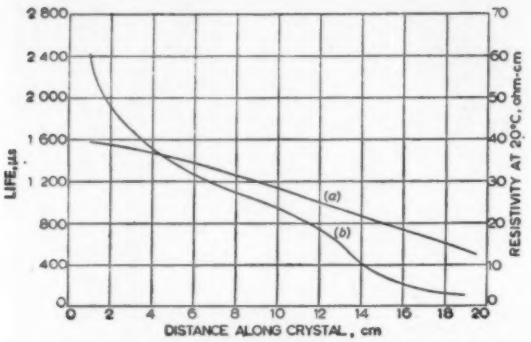
It is the usual practice at this stage of crystal production to add a small quantity of donor impurity in



2 *Lattice defects in a single crystal*

Etch pits on the surface of a single crystal, being the sites of the emergence of a row of edge dislocations at a tilt boundary. Angle of tilt, 1–2 seconds of arc. Magnification, × 210.

order that the crystal will be not pure but *n*-type. Typical elements used for this are antimony and arsenic. The impurity is added to the crucible before heating, and forms a homogeneous solution when the metal is melted. If the crystal were pulled out at a constant rate the concentration of impurity in the melt, and consequently in the solid crystal, would increase owing to the unequal solubility of the impurities in the liquid and the solid, and this would give rise to a change in resistivity along the length of the crystal. However, if the rate of pulling is

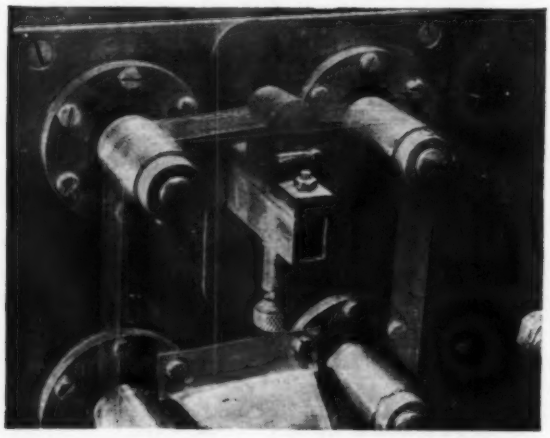


3 *Resistivity and lifetime characteristics of germanium crystal*
(*a*) Resistivity. (*b*) Lifetime.

continuously changed, the deposition of impurities in the solid can be made fairly constant.

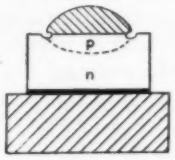
Tests on the variation of resistivity and of the lifetime of minority carriers along the length of the crystal are carried out, and Fig. 3 shows typical curves. As a standard of comparison the resistivity of the purest germanium obtainable is about 65 ohm-cm. For the purposes of rectification the lifetime of minority carriers should be at least 500 microsec, and so only two-thirds of this crystal would actually be used.

4 *Method used for slicing and for dicing germanium crystal*



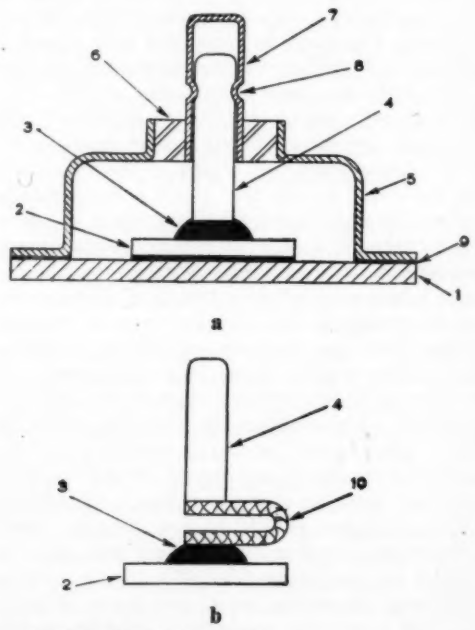
Manufacture of the Rectifying Cell

The single crystal of *n*-type germanium is virtually the raw material from which the rectifier is made, and it is first necessary to cut the cylindrical crystal into slices about 0·02 inch thick. In view of the high production cost of the crystal the cutting must be done with maximum economy, and ordinary techniques waste as much

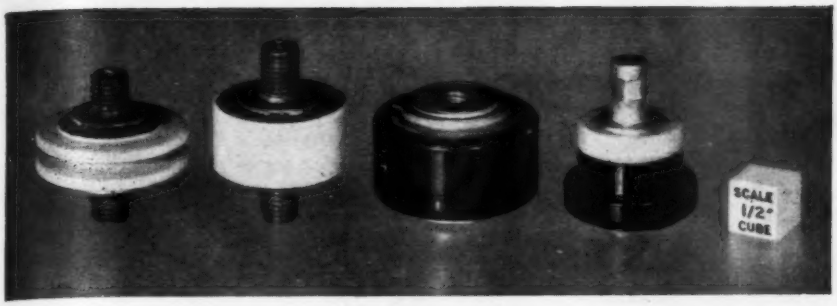


5 *The* p–n *junction cell in diagrammatic form*

material in the thickness of the cut as is used in the actual slice. An entirely novel method has therefore been developed, in which a number of slices are sawn simultaneously by fine tungsten wires coated with abrasive dust, as shown in Fig. 4. The wires are held in tension against the crystal and driven backwards and forwards three times a second through a distance of one foot each way. The method permits the cutting of 40 slices per hour. The crystal slices, or wafers, are subsequently etched to eliminate traces of contamination of the surface with tungsten or abrasive.



6 *Section of rectifier assembly*
(*a*) Normal connection. (*b*) Alternative connection.
1. Base.
2. Germanium wafer.
3. Indium.
4. Copper electrode.
5. Metal body.
6. Insulator.
7. Upper terminal.
8. Crimp.
9. Hermetic seal.
10. Flexible connection.



7 *Typical germanium rectifier cells*

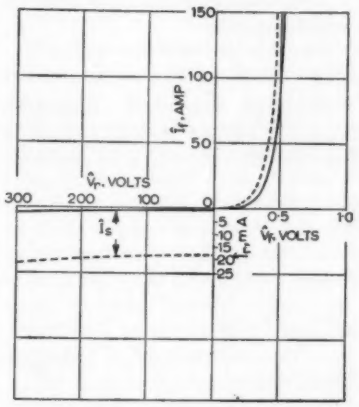
In the manufacture of a given rectifier cell, the wafer is soldered to a rigid base made of metal which has high electrical and thermal conductivities and about the same coefficient of expansion as the germanium. The actual formation of the *p-n* junction now takes place. An acceptor-impurity element, having a valency lower than that of germanium, is fused to the other side of the wafer, the element most appropriate for the purpose being indium. A pellet is placed on the surface and the cell is heated in an inert gas to 600° C, when the indium fuses and dissolves the germanium. The molten indium diffuses into the solid germanium converting the *n*-type material to *p*-type in the region of the interface. The thickness of the remaining *n*-type region, upon which the forward-current characteristics depend, is determined by the temperature and the quantity of indium present, and so a good measure of control is effected. The cell at this stage is shown diagrammatically in Fig. 5. The circular groove at the *p-n* junction is caused by electrolytic etching, carried out to ensure that all traces of impurity at the thin emergent edge of the junction are removed.

After the cell has been tested the assembly is usually completed as shown in Fig. 6(*a*). Great importance is attached to the hermetic seal which encloses the cell and prevents contamination in service. Fig. 6(*b*) shows an alternative method of connecting the copper electrode to the indium pellet, designed to prevent mechanical strain on the rectifier. The finished appearance of some of these cells may be seen from Fig. 7.

Rectifier Characteristics

The general characteristics of germanium rectifiers are similar to copper-oxide or selenium rectifiers, and current/voltage curves for the high-power type are shown in Fig. 8. The forward current varies little with temperature, and the voltage drop is always small. The inverse characteristics, on the other hand, show some variation in magnitude, and the dependence on temperature is much greater, the current roughly doubling for each 10° C rise in temperature. As the voltage is raised, at a given temperature, the current remains roughly constant, until the peak inverse voltage is approached, when the current rises steeply. This occurs when the impact of fast-moving electrons on the lattice electrons displaces them from their orbits and increases the number of carriers. The Zener breakdown, caused by electrons being torn from their orbits by the strength of the electric field, is not thought to take place in the germanium rectifier.

The peak inverse voltage decreases with the temperature rise and it is usually determined empirically for any given temperature, calculation being complicated owing to the current multiplication at high voltages. For example, in a typical rectifying cell it would be about 600 volts at room temperature and about 400 volts at 70° C (the rating of such a cell would be very much lower to provide a safe margin for overloads). The temperature of the junction should not be allowed to rise above



8 *Typical 50 c/s characteristics of a high-power germanium rectifier cell*

—— 25° C. – – – 70° C.
$\hat{I}_f$, $\hat{V}_f$ represent peak current and voltage in forward direction.
$\hat{I}_r$, $\hat{V}_r$ represent peak values in reverse direction.

100° C or damage may result. This temperature limit is, however, an advance on the limit of 75° C when work on germanium devices first started. The frequency at which the rectifier can be operated is also limited by the hole-storage effect, but this is no handicap for normal purposes. With increase of frequency there is a progressive decrease of efficiency, but high-power rectifiers have been operated successfully up to 500 c/s.

Every cell is tested and graded according to its peak

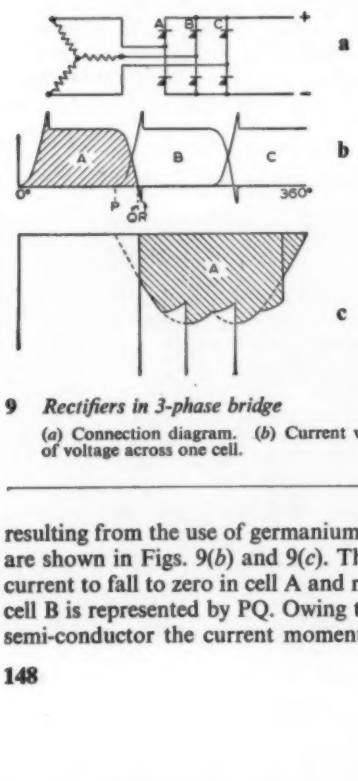
inverse voltage and the power which it can handle, the high-power rectifiers being subjected to specially stringent examination. If several cells are to be connected in parallel it is important that the forward voltage drop should be within $\pm 6\%$ of a standard value in order to prevent unequal current-sharing and consequent overloading of some of the cells. The amount of overloading which a cell can withstand is required to be at least eight times its normal current for three half-cycles, which would allow plenty of time for the contact-breaker to open. To guard against breakdown of a cell separate fuses may be placed in subdivisions of the circuit. Germanium power rectifiers appear to exhibit no ageing effect, although such an effect would be difficult to assess in the limited time—at the most two years—that these devices have been in service.

When *p-n* junction devices were first made many failures were reported that were attributed either to surface contamination or to faulty hermetic seals, which allowed the ingress of moisture, causing consequent chemical reaction on the surface. Since the production of high-power rectifiers started in 1952, however, no failures from these causes have been reported. Fortunately, germanium is largely protected against impurities by the existence of a natural insulating oxide film on its surface.

On this experience it is reasonable to hope for a life of 100 000 hours for the rectifying cells.

The Rectifier in Operation

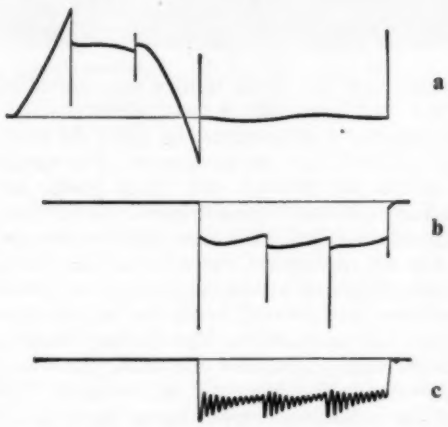
The simplest and most usual method of connecting cells of 1 or 2 kW rating is the 3-phase bridge connection shown in Fig. 9(*a*). The current and voltage waveforms



9 *Rectifiers in 3-phase bridge*

(*a*) Connection diagram. (*b*) Current waveform. (*c*) Waveform of voltage across one cell.

resulting from the use of germanium rectifiers in this way are shown in Figs. 9(*b*) and 9(*c*). The time taken for the current to fall to zero in cell A and rise to its full value in cell B is represented by PQ. Owing to hole storage in the semi-conductor the current momentarily overshoots the zero axis in the reverse direction causing a slight overload of cell B at the same time. This phenomenon gives rise to sharp voltage-spikes, which could damage the cell, and, by virtue of the following oscillations, cause interference with radio reception, but they may be rendered harmless as shown in the oscillograph records of Fig. 10, by connecting capacitors across the a.c. terminals of the bridge, when the reverse current merely flows into the capacitors.



10 *Oscillograms of a 3-phase bridge rectifier*

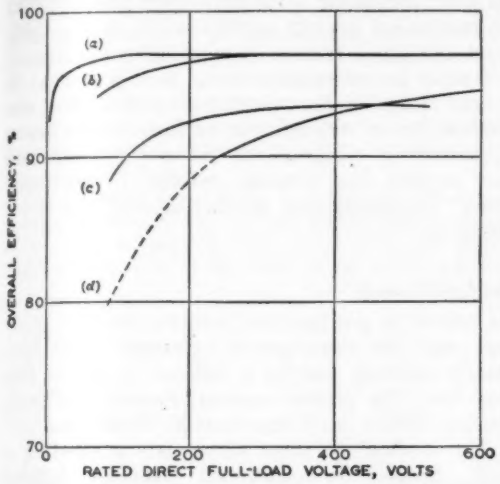
(*a*) Current in a rectifier cell. (*b*) Voltage across the cell. (*c*) Voltage after fitting capacitors.

In many high-power applications it is necessary to connect cells in series or parallel or both series and parallel. For these purposes they should have substantially similar characteristics, but if there is some variation between them it is best, when connecting in series, to shunt each cell with a high resistance, or, when connecting in parallel, to protect each cell with a low series resistance which equalizes the current in each branch. However, if high efficiency and simplicity of construction are required it is better to reduce the average current slightly so that no cell will be overloaded, and then to connect cells directly in series or in parallel without using protective resistors.

Since the junction temperature must be kept as low as possible for efficient operation and should certainly not rise much above 70° C, the temperature of the metal base should not exceed 55° C. From considerations of cheapness, simplicity and reliability, the best cooling medium is air, and it is the one mainly used. Small rectifiers equipped with fins may safely rely on natural convection currents, but high-power types require an artificial draught provided by a fan. In the event of a failure of the fan the current is automatically cut out. The provision of an auxiliary fan would eliminate delay in restoring the supply. In tropical countries, or in places where the air is exceptionally corrosive, some other type of cooling may be necessary. Water cooling has been used but it is clearly not desirable where cells are at different potentials.

Immersion in a water-cooled oil bath is another method, but the size of the apparatus is then increased, with the loss of one of the advantages of the germanium rectifier.

The efficiencies of the various types of rectifier operating over a range of voltage are shown in Fig. 11, from



11 *Efficiencies of various convertors for 15 kA operation*
(*a*) Germanium rectifier. (*b*) Contact rectifier. (*c*) Motor convertor. (*d*) Mercury-arc rectifier.

which it can be seen that not only is the germanium rectifier as efficient as the mechanical contact rectifier at high voltages but that it maintains a high efficiency at quite low voltages.

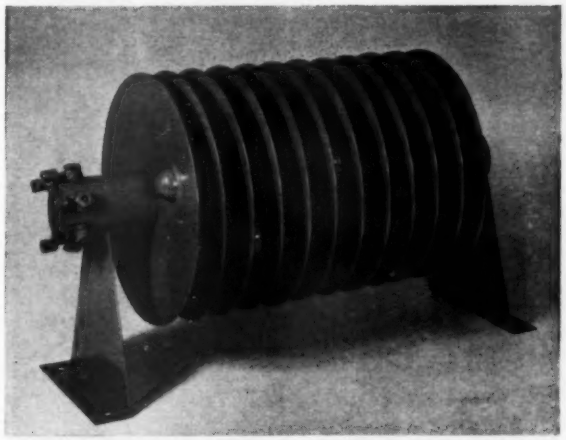
Voltage control of the germanium rectifier can be achieved by regulating the voltage from the transformer, and although the method is not as simple as the grid control of a mercury-arc rectifier, a smoother waveform is obtained.

Silicon Rectifiers

This article has concentrated on the germanium rectifier because that is the only type in actual production in this country, but a considerable amount of research has been carried out on silicon. This element is similar to germanium but it has one great advantage—the reverse current is very much smaller and so a *p-n* junction made from it can operate at much higher temperatures, 300° C being quite safe. Silicon is an abundant element in the earth's crust, but because of its higher melting point (1415° C compared with 958° C) it is much more difficult to purify than germanium, particularly to the extent required for semi-conductors. Silicon power rectifier cells of ratings greater than 1 kW have been made in the laboratory and the production problems are at present being tackled.

Applications and Economics

The possible applications of the rectifier are too numerous to quote exhaustively. Low- and medium-power types have found use in small battery chargers and power supplies for electronic equipment, being particularly useful in aircraft where small volume and low weight are important considerations. The small size of the high-power rectifier makes it very attractive for use in electric-traction vehicles and a small, air-cooled unit for use in electric trucks is shown in Fig. 12.

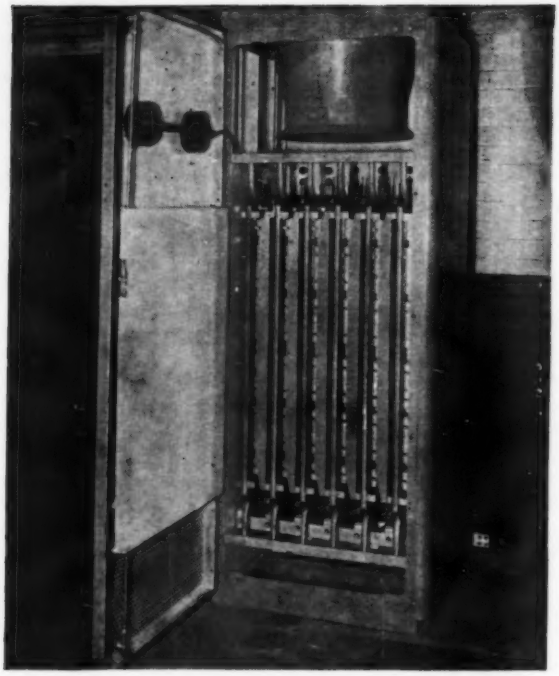


12 *Experimental stack of high-power germanium cells*

The high efficiency of the rectifier at low-voltage high-current outputs makes it unrivalled for use with electrolytic plant. A 300 kW assembly, shown in Fig. 13, has been in use for this purpose for two years at one factory where it replaced a mercury-arc rectifier occupying more than twice its floor area. It runs silently (except for the electric fan) at 6% higher efficiency and effects a saving of £700 a year on power. Another assembly of similar power and only half the size has been operating in the same factory for over a year, and another, rated at 1 MW and 255 volts, started service in 1955. Work is now proceeding on an 18 MW installation, which will be the largest of its kind in the world.

The cost of a germanium power rectifier is best seen by comparison with, say, the mercury-arc rectifier, since the cost of the former varies with the power (i.e. with the number of cells in the circuit) while the cost of the latter varies with the current. In both instances the cost of the transformer varies with the power. In consequence the curves of relative costs for both types cross, the germanium rectifier having the advantage at lower voltages and the mercury-arc rectifier at higher voltages. Based on present-day costs the point of intersection of the curves is around 400 volts d.c. but this figure is not based on a great volume of evidence and must be treated with reserve. As experience is gained in the application of germanium to power rectification, and as more efficient methods of manufacture are devised, it is expected that the point of intersection will rise very appreciably.

With the advance of techniques, experimental cells capable of handling over 100 amp have been made, and



13 *300 kW germanium rectifier assembly in cubicle*

commercial production is believed to be possible. It is expected that amplifying and power-control devices similar to the thyratron will also be developed in the future, and that the conversion efficiency of the germanium rectifier will be still further improved.

The main competitor of the germanium power rectifier is the mechanical contact rectifier which is also fairly compact and has at present an even higher efficiency of 98·2% while its maintenance costs have proved to be very low. However, the germanium rectifier has also shown itself to be very reliable, no interruption having yet occurred in service, and, while the mechanical contact rectifier has virtually reached its maximum efficiency, the germanium rectifier is still undergoing improvement.

Production Methods

The advent of *p-n* junction rectifiers has been fairly sudden, and the construction techniques have been constantly evolving, making it difficult to plan a production line. The present method, therefore, is batch production under semi-experimental conditions, but work has reached the stage when mass production is possible. Special air-conditioned buildings without windows will be required for this in order to obtain perfectly clean working conditions. The resulting increase in reliability and reduction of cost should make these new devices increasingly popular throughout industry.

CORRESPONDENCE

Negative Phase Velocity

From JOHN BROWN, M.A., PH.D., ASSOCIATE MEMBER

The possibility that the phase velocity of a wave travelling in certain types of corrugated waveguide and the velocity with which the energy flows may have opposite signs has been demonstrated by Mullett and Loach.[1] These authors make the physically reasonable assumption that the energy velocity is positive and the phase velocity negative. In the type of guide they consider, the energy velocity is equal to the group velocity so that this too is taken to be positive. On the other hand, Stratton[2] implies that in the more complicated case of lossy materials, the group velocity may be negative, so it is of some interest to consider whether the assumption of Mullett and Loach can be justified. A very simple application of Foster's reactance theorem shows that it is.

Consider a section of the waveguide of length l, terminated by a short-circuit. The input reactance of such a section is $Z \tan \beta l$, Z being the wave impedance of the guide, and β the phase-change coefficient. Foster's theorem states that the derivative of this reactance with respect to frequency must be positive, giving

$$\frac{dZ}{d\omega} \tan \beta l + lZ \frac{d\beta}{d\omega} \sec^2 \beta l \geq 0 \quad . \quad . \quad . \quad . \quad (1)$$

where ω is the angular frequency.

This result applies for any length, and the particular case for which βl equals π shows that

$$\frac{d\beta}{d\omega} \geq 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

since l, Z and $\sec^2 \beta l$ are necessarily positive. But the group velocity is $d\omega/d\beta$ so that equation 2 implies that the group velocity, and hence the energy velocity, must be positive. Accordingly for loss-free guides, to which this proof is restricted, Foster's reactance theorem requires that the energy velocity must always be positive, and when there is a sign difference, it is the phase velocity which must be negative.

1 MULLETT, L. B., and LOACH, B. G.: 'Waveguide Systems with Negative Phase Velocity', *Nature*, 1952, 169, p. 1011.
2 STRATTON, J. A.: 'Electromagnetic Theory' (McGraw-Hill, 1951), pp. 330-340.

Dr. Brown is in the Electrical Engineering Department, University College, London.

Time-Lag in Photoconductors for Camera Tubes

From W. R. DANIELS

Since the introduction of a practical camera tube based on the photoconductive effect, one of the properties of the photoconductive materials used which has been extensively investigated is the so-called 'lag,' which is observable in the signal produced by such a tube.

Much of the work carried out has had one of two objects:

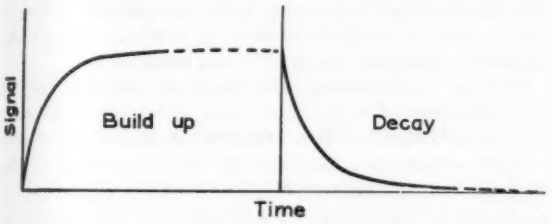
(i) To reduce the lag to an extent which permits the tubes to be used in broadcast television applications.

(ii) To increase the lag in a controlled manner so that the tube can be used as a storage device in some radar applications.

The purpose of these notes is to describe briefly some of the effects observed during investigations by myself and colleagues, but no attempt is made to explain all of them.

It does not appear necessary to describe here in detail the mode of operation of photoconductive camera tubes. It is sufficient to say that the photoconductive material is deposited in a thin layer onto which a light image of a scene to be transmitted is focused. Variations of the light content of the image cause local variations in the conductivity of the layer. These variations are evaluated by a scanning beam for generating the required signal.

The lag being investigated is a two-way effect, i.e. the change in conductivity of the layer lags behind the application of the light and the restoration to 'normal' lags behind the removal of the light or the action of the scanning beam.



The Figure shows the sort of curves which may be obtained both on building-up and on decay, but these curves must not be interpreted literally even on a comparative basis, for they vary considerably with the material, method of preparation of the layers and mode of operation of the tube.

It has long been recognized that the lag has two major components: (i) that due to the capacitance of the layer; (ii) that due to 'hysteresis' effects in the layer.

The capacitive effect is comparatively simple and has been discussed recently by Webley *et al.*,[1] but the hysteresis effects are much more complex. A series of papers[2] published in 1951 dealt with the properties of some of the materials used in these layers; in particular, one of these described fully the mechanism of *trapping*, which was suggested as being the cause of the hysteresis effects.[3] Our own observations, however, do lead to the belief that some mechanism other than trapping is responsible for some of the effects noted.

Amorphous selenium, which is one of the target materials used in photoconductive camera tubes, frequently exhibits a negatively retained signal of the original picture, visible when the target is exposed to light. This effect can last up to several minutes, but is hardly ever permanent. The period for which this negative signal persists becomes shorter as the target bias during exposure is raised, passes through zero and then becomes a positive persistence. Unfortunately the background of the picture due to imperfections in the photoconductive layer becomes generally intolerable at a target bias which produces negligible persistence. There is no loss of sensitivity in the area showing the negative signal, and so the effect cannot be referred to as fatigue. Further, the signal amplitude increases with increasing target bias, whereas the negative retention of the signal decreases. No explanation for this behaviour of amorphous selenium seems to be available.

Another material used for photoconductive targets in camera tubes is antimony trisulphide. Its inherent lag as normally used is considerably greater than that of amorphous selenium, but this can be reduced by deposition in a gas atmosphere. Targets deposited in this manner are liable to retain the signal permanently, a process often called *burn-in*. In severe cases there is even a change in the appearance of the layer material. The scanning beam alone can cause the burn, but a combination of light and scan is very much more effective. The resistance to burning-in a signal is not constant during the life of the camera tube but increases in time as the target is scanned. There is little evidence that this burning-in is due to fatigue, since no loss of sensitivity has been found in burned-in areas, but it would appear to be a stabilizing of the layer at a different level of dark resistance. Targets deposited in such a way that they become very liable to burning-in can be stabilized by suitable treatment.

One explanation for this effect is that carriers flowing across the target change its resistance in a permanent manner. This would be acceptable if the burned-in picture was always of the same polarity. Indeed, these targets exhibit generally a positive burned-in signal, but there are some which show negative burns. The carriers flowing across the target should affect its resistance in always the same manner.

It has been found that when a photoconductive camera tube with its target deposited in a gas atmosphere is set up so that the highlight signals in the picture are not fully discharged by the scanning beam, the risk of burning-in the picture is increased. Both positive or negative burns can be obtained in this way, although the tube may have worked at a higher output for a considerable time without showing this effect, if sufficient beam current was available to discharge the highlight signals completely. Two highlights of different intensity, both not fully discharged by the scanning beam, will burn-in at different levels. It is likely that the potential gradient across the target in these insufficiently discharged areas differs from that under fully discharged operation and creates conditions under which burn-in takes place.

Permanent burn-in in vacuum-evaporated antimony trisulphide does not occur, unless the material is overheated to such an extent that it has changed into the more conductive form, which takes place at a temperature far greater than that at which burn-in of signals in layers deposited in a gas atmosphere is obtained.

Conclusion. These observations are reported in order to indicate that the present published information on the photoconductive type of camera tube, and the layer materials used in them, is far from sufficient to account for the effects observed. They also confirm that the method of investigation, i.e. by incorporating a layer of the material in a camera tube in which it can be subjected to light and to electron-beam scanning, is a very sensitive method of carrying out such investigations into the properties of those materials which are suitable for this purpose.

The investigations are continuing, and it is intended to publish a more extensive report at a later date.

The author wishes to thank the Directors of Cathodeon Ltd., Cambridge, for permission to publish this communication.

1 Webley, R. S., Lubszynski, H. G., and Lodge, J. A.: 'Some Half-Tone Storage Tubes', *Proceedings I.E.E.*, Paper No. 1883 R, July 1955 (102 B, p. 401).

2 Weimer, P. K., and Cope, A. D.: 'Photoconductivity in Amorphous Selenium', *RCA Review*, September 1951, p. 314.
Forgue, S. V., Goodrich, R. R., and Cope, A. D.: 'Properties of some Photoconductors principally Antimony-Trisulfide', *RCA Review*, September 1951, p. 335.
Smith, R. W.: 'Some aspects of the Photoconductivity of Cadmium Sulfide', *RCA Review*, September 1951, p. 350.

3 Rose, A.: 'An Outline of some Photoconductive Processes', *RCA Review* September 1951, p. 362.

Mr. Daniels was formerly with Cathodeon Ltd., and is now with 20th Century Electronics Ltd.

M.K.S. UNITS FOR SCHOOL PHYSICS?

Some Practical Views on an Important Report

The past few years have heard much discussion by both electrical engineers and physicists—especially those engaged in teaching—about the use of M.K.S. units, and, as recent correspondence in the *Journal* has exemplified, there exists a surprising conflict of opinion on their fundamentals (though much agreement on their practical advantages). In 1951 the Science Masters' Association appointed a committee to consider their desirability and practicability in the teaching of science in secondary schools, and some fifteen months ago the committee's Report was published as a book.* Below are printed five reviews of the Report by practising schoolmasters in public and grammar schools, which, it is hoped, will interest and be useful to members in giving them a sample of opinion in schools about M.K.S. units.

Methods of teaching electricity and magnetism in schools are, of course, important in relation to the *scientific training* of future physicists and electrical engineers and to the startling—almost terrifying—need to guide more boys and girls into scientific or technological walks of life. However, many of those learning physics at school are not embryo physicists or engineers and what may be helpful to later training is not necessarily *educationally* so attractive. In this context schoolmasters can hardly side-step the prickly question of the usefulness of M.K.S. units in branches of physics other than electricity and magnetism; rather unexpectedly, although this question is within their terms of reference, the S.M.A. committee appear to dismiss it in one paragraph.

Professor E. Bradshaw, who has given much thought to the application of M.K.S. units, and whose book* on them has proved helpful to many electrical engineers, has written a short commentary summing up the five reviews of the schoolmasters, which is printed at the end.

* THE TEACHING OF ELECTRICITY: WITH SPECIAL REFERENCE TO THE USE OF M.K.S. UNITS: A Report of a Sub-Committee of the Science Masters' Association (John Murray. 147 pp. 10s. 6d.).

* See Review No. 5, Reference 3.

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1 By P. C. GIBBS, M.A.

Senior Physics Master,
PORTSMOUTH GRAMMAR SCHOOL

In view of the statement, on page 6 of the Report, that 'this country can no longer afford the luxury of the point-pole approach', a potential critic must pause and weigh microscopically any destructive phrase which he has in mind. It is clearly undeniably true that, as is suggested in the same paragraph of the Report, space must be found in the school teaching syllabus for an introduction to the principles of some extra basic tools of the electrical engineer. Specifically the most important of these are surely the effects of electric and magnetic fields in alternating electric circuits, the elements of thermionic vacuum tubes and perhaps even a grounding in semi-conductors.

The clearly stated dual aims of the Report, namely (i) the introduction of the rationalized system of M.K.S. units, and (ii) the omission of all the syllabus dealing quantitatively with magnetism concentrated in poles, can, when achieved, obviously in principle prune the existing syllabus. These aims, reported as the agreement of a body of most experienced educationalists, cannot be cast lightly aside, but whether the suggested approach to their achievement will satisfy the needs of the average secondary-school sixth-former appears to me not a little doubtful.

In the most general terms, the syllabus as outlined at the beginning of Chapter II seems to contain too much that is purely academic and beyond the reach of the majority who will be aiming for a pass at A level of the G.C.E. The 'additional topics' outlined on page 18 must surely constitute at least three-quarters of the average examination syllabus at this level; and it is at the A level that the pass candidate gains the broad background of experience against which he can most easily face later the need to examine critically the foundations of the subject and its systems of units. To remove completely the fundamentals of classical electrostatics would seem both unnecessary and undesirable, for their use most certainly gives a rapid and direct approach to electric field theory applied to simple electronic problems.

The Report speaks of replacing magnetometry and classical electrostatics by 'a simpler and more practical approach based on uniform fields produced by a solenoid and a parallel-plate capacitor'. Little can, however, be found in it about, first, apparatus to give suitably large-scale uniform magnetic fields (the solenoid in Experiment 3 gives a field variation of 10% in 15 cm), and secondly, any experiments designed to give the large, and very average, classes of to-day that fundamental experience of force in fields, which is perhaps one virtue of magnetometers, and which is so notably lacking in the suggested treatment of electric fields.

On points of detail I feel that the claim that nomenclature in the M.K.S. system is simplified is an exaggerated one, and the reference to the Fighting Services' training manuals on page 3 will no doubt recall for many the drawn-out demise of the *jar*.

The analogue of B as strain and H as stress is perhaps dangerous, requiring, as it inescapably does, the return to the mechanical properties of an aether. The numerical value of μ_0 is, furthermore, a fiction—convenient though it may be—which is even more difficult to tolerate than that of 4π lines per unit pole. Frequent reference is made to Maxwell's relation $\epsilon_0 = 1/\mu_0 c^2$ with the implication of some depth of knowledge of the interaction of electric and magnetic fields, and this again will surely not appeal to the more careful schoolmaster.

It would be churlish not to acknowledge at some stage in this review the very evident valuable wealth of detail given in the second half of the book in F. A. Meier's experiments. Experiments 1 to 3 constitute no change in well-established practice, nor perhaps do the principles of Experiments 10 to 13, but the painstaking completeness in the accounts must be among the most useful features of the Report. It must be open to question, however, whether the 'set-piece' nature of most of these can provide schools with the basis for the class experiments of the practical course.

In conclusion, since simple ideas of the atomic and nuclear structures of matter depend upon laws of force of an inverse-distance pattern, to excise completely this solid foundation from our electrical teaching is to deny what may yet prove to be the key link to the complete integration of physics as the prime study in the material world. The place for the introduction of the scheme of this Report perhaps is, at the earliest, in a final post-A-level year at school, or in a first-year university course.

2 By The Rev. A. W. V. MACE, B.SC.

Senior Physics Master, RUGBY SCHOOL

As will be seen from the title of the Report, the committee responsible have restricted their considerations to the teaching of electricity, for which the M.K.S. system has special virtue. The common practical electrical units fit into it without additional derivation; while if one basic unit is further defined, the theoretical electromagnetic and electrostatic systems are also in effect made to fit, without their present incompatibility.

Thus there is a strong case for adopting the M.K.S. system in teaching electricity, and the committee made this their first recommendation. Secondly, and as much a revolution in school practice, it is proposed that the development of electromagnetism should no longer be based on the concept of magnetic fields as arising from point poles, with its associated teaching of magnetometry. Instead, the approach suggested is via the uniform field inside a solenoid, with magnetic intensity expressed in terms of its surface density of current. The final recommendation is that a rationalized M.K.S. system should be employed. There follows a suggested sixth-form electricity syllabus embodying these principles; some notes on the definition of practical units such as the ampere, where the recent international definition is adopted; and a series of theoretical propositions worked out in the form required by the new approach.

So far the Report scarcely kindles the enthusiasm which the committee feels for its proposals. There are several reasons. First, so much space is taken to justify a rationalized M.K.S. system, on the grounds of geometrical neatness, that the real power of any M.K.S. system is insufficiently demonstrated. (As the report elsewhere directly borrows from *The School Science Review*, it is a pity that Professor G. H. Rawcliffe's convincing article on 'The M.K.S. System of Units' in the October, 1949 issue, is not reprinted, rather than being referred to by footnote.) Secondly, the opening theoretical proof is most discouraging. It obtains the value of the magnetic field near a linear conductor by the device of filling the space around this with an infinity of toroids, which then disappear after the fashion of the Cheshire Cat, leaving only its grin, in the form of the current and its field. Most schoolboys will regard this legerdemain as 'phoney', and will be suspicious of the whole subject in consequence. Again, the second proof—of the field due to a current element of conductor—requires the arbitrary introduction of a constant, 4π, which seems to refute the geometrical neatness claimed for the rationalized system.

Far more serious is the fact that the committee have considered only the subject of electricity. Much stress is laid on 'maintaining the structure of the syllabus': but the other branches of physics have been ignored in this connection. There must also be a cross-structure relating to them, if the unity of the whole is to be maintained, and to apply M.K.S. units to electricity alone makes it seem to stand apart from the rest of physics. It would have been profitable, too, to have considered whether the abandonment of the inverse-square law did not destroy valuable cross-links with light and gravitation, or, alternatively, to discover whether the flux conception could be successfully applied to these studies also. Until considerations such as these have been more carefully examined, many teachers will be unwilling to adopt a scheme which may well prove to be one-sided.

However, the last, and major, section of the Report will appeal to all teachers, whatever their other reactions. It consists of a series of experiments designed to implement the new syllabus, together with an appendix giving hints on the construction of the necessary apparatus. All this is the work of that prince of physics teachers, the late F. A. Meier, and this is sufficient guarantee that the experiments described are suitable for school use, even though they include such adventures as measurement of resistance by the Lorenz method. All physics teachers, whether they adopt the M.K.S. system or not, will find much that is profitable in this part of the book, and be glad that it contains so fitting a memorial of one of the most gifted members of their profession.

3 By ROBERT MOSS, M.A., B.SC.

Head of the Science Department, WELLINGTON COLLEGE

No schoolmaster who was privileged to see the late Mr. F. A. Meier demonstrate his fascinating experiments to the Science Masters' Association could have resisted his infectious enthusiasm, nor could he have failed to resolve that he would try to repeat them for the benefit of his own pupils. For many of us, fulfilment of this laudable resolution has had to await publication of a handbook on 'How to do it'. This has now appeared, being the Report under review here.

Every electrical engineer who has had to learn the three classical systems of units will sympathize with the schoolmaster who not only has had to learn them too, but who in addition has to justify them to his inquiring pupils; he will see why there is likely to be general agreement with the first recommendation of the committee, 'that the rationalized M.K.S. system of units should be adopted'. If this involved a change of the units only, the innate conservatism of most teachers would no doubt give way as readily as it did some years ago when order was brought to the conflicting sign conventions used in the teaching of optics: but difficulty may arise over the second recommendation, 'that all quantitative treatment of magnetic poles should be omitted from the school syllabus, thus permitting the introduction of other, more important, topics and the development of electromagnetism on entirely new lines'.

The development of trained minds, rather than the inculcation of technical knowledge or professional skill, being the primary object of a public school, one may question whether the new approach will bring advantages so great that it would be right to disregard its repercussions on the economical employment of present teachers and of existing equipment in laboratories and libraries.

Appendix A gives most lucid and helpful instructions for making the apparatus required in the experiments of Chapter VI, but few schools have enough laboratory assistants, and few science masters have enough freedom from other activities—that is, if they are playing their part fully in the wider, non-scientific life of their school—to be able to make all that is required for quite some time to come. It is essential to be fully equipped before making any change; half measures would lead to chaos. No doubt, the commercial laboratory furnishers could produce the gear, given time, but 'home-made' apparatus is usually more stimulating to boys.

What may take even longer is the re-orientation of the teachers' outlook. A physicist who has already encountered philosophical difficulty in, for instance, the various interpretations of the relationship between B and H, will quickly perceive the beauty and apparent certainty of the new approach—although he will also recognize that it conceals rather than eliminates some of the problems—but what of the mathematician or chemist? The former may be reluctant for instance to surrender the satisfying formal analogies between the point-pole aspect of magnetism and the other instances of Newtonian attraction; the latter may not easily see the alleged advantages of such concepts as the measurement of permeability in 'henrys per metre'. Yet many chemists and pure mathematicians are doing invaluable work by teaching electricity and magnetism to sixth forms during the present shortage of physicists. They will require a good deal of help before they are ready to cope with such a fundamental change.

No doubt the change will come sooner or later, for teaching must come into line with the system actually used by practising engineers. Some of the school examining bodies have already notified their willingness to use it in their question papers, but the policy which is so admirably stated in the Report can hardly be put into effect until an appropriate textbook has been written for the pupils themselves.

4 By T. Y. PRICE, M.A.

Senior Physics Master,
BRADFORD GRAMMAR SCHOOL

This Report forms an interesting and persuasive argument for making a change in the conventional method of teaching electricity and magnetism in schools. In making a definite recommendation for the use of the *rationalized* system of M.K.S. units, the committee responsible for this Report have done well, for in the last big change in teaching method—that of sign convention in optics—the committee reporting on it were unable to agree upon a single convention, but gave their blessing to two, so that much duplication of textbooks and methods resulted. It is much to be hoped that all those who change from the historical method of teaching electricity and magnetism will accept the recommendation of rationalized units.

The first chapter summarizes the proposals of the committee. Briefly, these are the abandonment or at least the postponement of the study of magnetism; the recasting of static electricity into a form centred on the condenser and the electric field rather than on charge; and the teaching of a rather artificial and difficult definition of the ampere. This change brings a really beautiful simplification of the units and calculations, with the *joule*, *coulomb*, *volt* and *watt* slipping quietly into their places as absolute units. There would be no powers of ten to memorize, and a great reduction in the number of units to be learnt.

Chapters II–V provide the skeleton for the textbooks that will doubtless be written in the future. The sixth chapter is probably the one of most interest to schoolmasters. It is by far the longest, and contains a series of experiments, some of them of extreme ingenuity and interest. Perhaps the most attractive is the adaptation of Lorenz's famous experiment on the ohm in a form which can be easily set up and worked in a boys' laboratory, but all are interesting, and many will be adopted even by schools which do not yet propose to change their method of teaching the subject.

Probably the change to M.K.S. units will eventually become universal, but it will not be a very swift one, since the necessary apparatus appears expensive to make. Then again, textbooks of fine, stimulating quality at scholarship standard are rare, and many schools will wait till a first-class book appears dealing with the subject in this way. Till then they will gratefully adopt the experiments and use them as a valuable help in the conventional study of the subject, gradually building up the necessary apparatus as opportunity arises.

5 By J. H. SHACKLEY, B.SC., A.INST.P.

Formerly *Senior Science Master,*
NEW MILLS COUNTY GRAMMAR SCHOOL, DERBYSHIRE

Full discussion on the case for, and against, the adoption of rationalized M.K.S. units has already taken place in the *Proceedings*,[1,2] and elsewhere[3,4,5,6] and it is not the purpose of this review to add to it. Suffice it to say that the writer believes it 'no kindness on the part of those who have reached a firm foothold'[7] to compel those who follow to use the same difficult stepping-stones, when an easier path already exists.

Before the war the study of units in general received scant attention either from schoolmasters or from others concerned with the teaching of electricity. Nor has this neglect entirely ceased: recently the chief physics teacher of a large technical college admitted that he knew little of M.K.S. units.

In common with others,[8] the writer had observed the unpopularity of electricity and magnetism compared with other branches of physics. Moreover, investigation showed that this sprang mainly from the confusion of units associated with the traditional development of the subject. Largely as a result of the discussion on the 'Symposium of Papers on the M.K.S. System of Units' at the North-Western Centre of The Institution, and a series of lectures given by Mr. L. H. A. Carr and Professor E. Bradshaw at the Manchester College of Technology, it was decided to try this type of approach with sixth-form grammar-school pupils.

At once two difficulties became apparent. First, the effect of 20 years' application of C.G.S. units and the point pole

made it difficult to view M.K.S. units without bias. Secondly, no suitable textbook existed combining both theory and experiment. However, a short course was designed, the results of which showed what has already been indicated, that the difficulties experienced in the study of electricity are largely the result of confusion of units. This conclusion was confirmed by the experience of one boy who, unable to attend the course because of illness, later became a student in electrical engineering at a technical college where the M.K.S. system is used.

Recognizing the difficulties which must be encountered when attempting to evaluate the M.K.S. system in practice, the Science Masters' Association has published the present Report. More than half of it is devoted to experimental procedure, an appreciation of the fact that classes, swollen almost to twice pre-war numbers, prevent most masters from conducting personal research in this direction. Here is no ordinary 'practical book'. In it will be found not only details of experiment but also complete specifications for the construction of apparatus. So lucid are these that the laboratory steward can work from them without supervision. Nor has theory been neglected. The reader will find that this has received equally thorough treatment and is amply supported by definitions.

One of the many valuable features is a teaching syllabus enumerated in complete detail with adequate cross-reference between theory and practice. The approach through uniform fields possesses the advantage of linking up with O-level studies, but everyone will not agree with this method.[9] This will be valuable because it will stimulate thought about the type of presentation. Thus, at a time when reform in the teaching of electricity in schools is under consideration, this book will prove invaluable to those who, though confined by examination requirements, may yet wish to experiment with a more modern approach.

Two minor misprints have occurred. On page 4 the formula for the capacitance of coaxial cylinders has a redundant 2 in the denominator, and the limits of integration should be interchanged in the expression for the magnetizing force associated with an infinitely long straight wire on page 42. One interesting point emerges; after more than 20 years of anonymity, the unit pole appears as a weber.

Dr. Boulind, the chairman of the committee, and his associates merit the highest praise for their attempt to help their fellow teachers to keep school electricity in step with modern practice, without which no subject can long remain vigorous.

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7 HAMMOND, P.: *ibid.*, p. 148.
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9 TRICKER, R. A. R.: 'On the Teaching of Electricity', *School Science Review*, 1954, p. 378; and 1955, p. 32.

A Brief Summing-up by Professor E. BRADSHAW, M.B.E., M.SC.TECH., PH.D., MEMBER

Professor of Electrical Engineering, Faculty of Technology, UNIVERSITY OF MANCHESTER

The foregoing views of five science teachers will be read with respect and their reservations noted sympathetically by those who have faced a similar problem in post-school education and who have now accepted whole-heartedly the M.K.S. rationalized system of units. One of the contributors admits frankly the difficulty of viewing impartially such a major change in teaching after an upbringing on the older unit systems. As far as experience in universities and colleges is concerned, I believe it fair to say that the change, once made, has been recognized by staff and students to be entirely beneficial.

Many of the reservations and objections relate, not to the unit system itself, but to suggested changes in the concepts and development of the science. Basically, this need not be too serious a stumbling block since a given method of approach may, in principle, be realized in *any* system of units. The fact that the rationalized M.K.S. system of units is particularly suitable for a development which places emphasis on the uniform-field concept should not be used to condemn the system by those who do not wish to accept this emphasis; some recent papers on electromagnetic fundamentals use a rationalized system whilst retaining a substantially classical approach.* Even though the inverse-square law is not made the basis of the sequence of development suggested in the Report, it is included (page 52) but it might well receive more emphasis than it does.

Several contributors refer to the need for school textbooks in the new system. At least one suitable sixth-form text is available.† It is to be hoped, however, that others will be forthcoming; there is room for various treatments within the framework of the new unit system.

The admirable suggestions in the Report for experimental work, due largely to the late Mr. F. A. Meier, are sufficient answer to the doubts of some of the contributors about possible difficulties in providing such work. Even if the apparatus required is a little more ambitious than the traditional equipment, the importance of the subject fully justifies the expenditure. The experiments described are intellectually stimulating and offer excellent opportunities for developing experimental technique. Some further work appears to be necessary in the field of electrostatics; there would seem to be a fruitful field here for educational research.

It would be presumptuous for one who has not to provide a solution for many of the problems of science teachers to say what should be done and how. It is, however, not without significance that their pupils will, after leaving school, be required to work, and read the bulk of their scientific literature in electrical science, in a system of units different from that used in their school days. This will apply not only to those who pursue the study of electrical engineering, but also to other technologists and many chemists, physicists, etc. The fact that this different system will appear to many as more unified and revealing must, in the long run, raise doubts in their minds as to the justice of their having been subjected to at least three systems of units at school, where one would have sufficed.

* See Reference 2 above.

† See Reference 5 above.

NEWS *from Abroad*

ARGENTINA

Notice has been received that the Committee of the Argentina Joint Oversea Group is now constituted as follows:

Chairman	R. M. Drysdale, A.M.I.MECH.E.
Vice-Chairmen	C. Mellor, A.M.I.C.E. R. A. Duncan, A.M.I.MECH.E., A.M.I.E.E.
Immediate Past-Chairman	R. G. Borissow, A.M.I.MECH.E., M.I.E.E.
Ordinary Members	T. B. Glover, M.I.MECH.E. H. Y. Buchanan, A.M.I.C.E. H. M. Piette, A.M.I.MECH.E. E. M. Whitaker, A.M.I.E.E.
Honorary Secretary and Treasurer	J. Combes, A.M.I.C.E., c/o Percy Grant & Co., Reconquista 314, Buenos Aires, Argentina.
Oversea Representative of the Council	A. C. Towers, M.I.E.E. (*ex officio*).

Members in Argentina are invited to get in touch with the Honorary Secretary of the Joint Group, who will be glad to provide them with details of the programme of meetings and visits which is being planned. The Group now has 118 members: 30 civil, 53 mechanical and 35 electrical engineers.

QUEENSLAND

During the 1955 Session, five meetings and the Annual Christmas Luncheon were arranged by the Queensland Oversea Committee under the chairmanship of Mr. J. S. Just.

The Annual Joint Meeting with the Brisbane Division of The Institution of Engineers, Australia, was held on 26th August, when approximately 80 members of the two Institutions gathered to hear a paper by Mr. W. H. R. Nimmo and Mr. E. M. Shepherd entitled *Hydro-Electric Development in Queensland*. Mr. Nimmo, who opened the lecture, described the hydrological aspects of North Queensland, from the Burdekin River northwards to the Barron River. Here in the ranges which lie relatively close to the coast line very heavy rainfalls are experienced, and on the main streams emanating from such sources a potential of over 300 000 h.p. is available for development. Mr. Shepherd, in his portion of the lecture, dealt with a number of the schemes which had been proposed, including the Tully Falls project (72 MW at 50% load factor) now under construction, the commissioning of which is expected to take place in late 1956.

At two of the remaining functions members heard lectures dealing with recent developments in the design and performance of radial-flow turbines, and in the design, voltage, size and application of large transformers. The relatively large attendance at these meetings—65 and 80 respectively—indicated once again the keen interest of members to hear the latest technical information delivered by oversea experts.

An address was given by Professor C. E. Moorhouse, Professor of Electrical Engineering in the University of Melbourne, who had recently returned from an oversea visit, on the varying conditions covering training schemes existing in Great Britain in the major electrical engineering works. On the 12th May there was a visit of inspection to the Department of Electrical Engineering, University of Queensland, Brisbane. This visit was of great interest to members, because amongst the apparatus exhibited was the recently acquired impulse testing plant. This plant, with a maximum output of approximately 900 000 volts, is being used for research and for tests of power-system equipment.

The Christmas Luncheon, which has become an outstanding annual function, was again held at the Bellevue Hotel, Brisbane, on the 8th December. In a congenial atmosphere, members, whilst refreshing the inner man, listened to an address delivered by the Commissioner for Electricity Supply in Queensland, Mr. H. N. Smith. The guest speaker took as his subject *Development of the Electricity Supply Industry in Queensland*, and gave members an outline of the progress achieved in the past 18 years, and an indication of developments which might be expected during the next decade. A. S. F.

UGANDA

Kampala Agricultural and Trade Show

The Agricultural and Trade Show held in the Nakivubo Stadium, Kampala, from the 15th to 18th December, 1955, was intended as a shop window for Uganda. At it the Uganda Electricity Board had a stand displaying a wide range of electrical appliances of interest chiefly to the domestic, commercial and workshop types of consumer. Throughout the Show it attracted large crowds who were especially interested by the demonstrations of various appliances with explanations in the native language. Cookery demonstrations in a small enclosed hall at the back of the stand holding 32 people were a great success, as were the film shows in between the demonstrations.

Although the Board have not as yet their own showrooms for selling appliances direct to the public they are striving to demonstrate how electricity can help to increase prosperity and improve standards of living, and they are ready to advise consumers on the choice of suitable equipment.

OVERSEA ATTENDANCE REGISTER

During the period 1st January to 31st January, 1956, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

BALL, D. H. (Singapore).
BRITTON, A. W. (Benin, Nigeria).
MILNE, W. G. (Krugersdorp, Transvaal).
PAUL, P. (Baghdad).
SNELSON, L. G. (Lagos).
SUTCLIFFE, J. B., M.SC. (Baghdad).
VOHRA, Brig. S. P., I.E.M.E. (New Delhi).

POWER FROM THE SNOWY MOUNTAINS

A Vast Project in South-East Australia

D. W. Soughan, ASSOCIATE MEMBER

The rain shadow cast by the Great Dividing Range has long been an obstacle to Australia's economic development. Great volumes of water pour wastefully back into the sea from the eastern slopes, while the waters of the Murray and Murrumbidgee Rivers must be carefully conserved to irrigate even a small part of the vast area on the western side of the range. With the building of a series of dams and tunnels in the Snowy Mountains the old dream of diverting the Snowy River from east to west will at last become a reality, while the exploitation of the enormous hydro-electric potential of the river system will enable abundant electric power to be transmitted to the booming cities of Sydney and Melbourne.

The author was engaged for some time on the Snowy Mountains Scheme and is now with the English Electric Co.

THIS short article reviews the Snowy Mountains Hydro-Electric project now under construction in Australia, which in January, 1955, produced its first power for the New South Wales system. With field investigations continually progressing, details of design are subject to revision and the installed capacity figures for the proposed power stations, taken largely from the 1950 report,* should therefore be read with reservation.

Proposals for the utilization of the waters of the Snowy River were first heard over 70 years ago, but it was not until after the Second World War, in the era of Australia's developing prosperity, that anything like firm action was taken. The Commonwealth and State Snowy River Committee was appointed in 1947, after discussions between the representatives of the governments of New South Wales and Victoria, and this committee issued its final report in 1949. The report was adopted by the ministers concerned and in the same year the Snowy Mountains Hydro-Electric Authority was set up by the Commonwealth Government and its headquarters established in Cooma, N.S.W.

The Existing Power Situation in New South Wales and Victoria

Sydney, in addition to having one of the world's finest harbours, lies near the centre of rich coalfields. It was thus inevitable that coal should have been first exploited for power generation from the earliest days, and, as a natural corollary, industries were developed in the area.

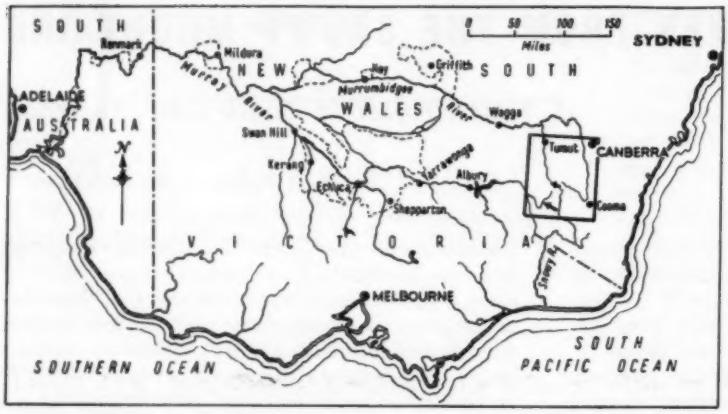
Whilst some hydro-electric installations exist in New South Wales, principally the Burrinjuck and Wyangala schemes, their combined output of some 27 500 kW represents less than 5% of the total installed capacity in the State. Since both the large water potential of the Australian Alps (see below) and the smaller potential of the Clarence River are situated some distance from the load centre of Sydney, it is easy to understand why water power has not been more fully exploited in the past.

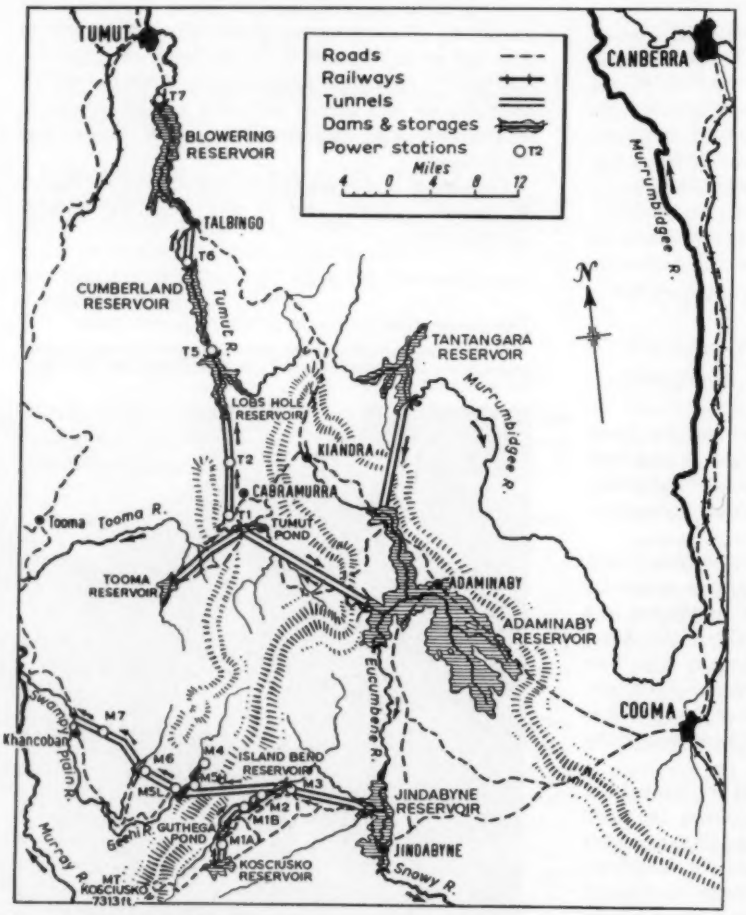
In the State of Victoria black coal deposits are limited but brown coal is plentiful, and the distances from the load centre of Melbourne to the sources of hydro-electric power are less. Thus brown coal is the main fuel for Victoria's steam power stations and it is most economic to operate these plants at a high load factor, whilst the steam plants operating on more expensive fuels work at a lower load factor. Existing hydro-electric installations in Victoria, namely the Kiewa, Sugarloaf, and the Rubicon schemes, at present amount to some 10% of the State's installed capacity and are operated in the system to the best economic advantage.

* "Proposals to Divert the Snowy River" (Final report by Commonwealth and State Government officers. May, 1950).

The Tumut River at the site of the T1 power station

This view gives an idea of the terrain in which the development schemes are being carried out. Contractors' huts can be seen on the river bank.





The Snowy Mountains Scheme

The lower map shows on an enlarged scale the area enclosed by the rectangle in the upper map. The shaded areas in the lower map give the positions of reservoirs when the scheme is completed; the townships of Adaminaby and Jindabyne will be flooded. The scheme consists in two main parts—the Snowy–Murray development, in which the Snowy is dammed in several places and its waters largely diverted through a series of tunnels and power stations to the Murray River, and the Snowy–Tumut development in which the Eucumbene River (a tributary of the Snowy) is similarly diverted to the Tumut River and thence into the Murrumbidgee. Not only will electric power be obtained by this means, but a greater volume of water will be delivered to parched areas. The complete system of rivers may be seen in the upper map, in which the existing irrigation areas are shown by broken lines.

The Keiwa and Sugarloaf schemes are still incomplete and thus hydro-electric power will, in due course, play a more predominant role in the power situation in Victoria.

In both States the present installed capacity is barely sufficient to meet the demand, and with the loads growing at approximately the same rate the demands for electric power in New South Wales and Victoria are expected to double themselves within the next decade. The Snowy Mountains scheme, being conveniently located between the load centres of Sydney (in New South Wales) and Melbourne (in Victoria), will accordingly play an increasingly important role in the Australian development story.

Geographical Features

Although the summit of Mount Kosciusko, Australia's highest point, rises to an elevation of 7313 ft, it is quite misleading to refer to the Great Dividing Range as mountainous. Indeed there are no great mountain ranges in the whole of the Australian continent. Rolling, heavily timbered, hilly country conveys a more realistic picture of these highlands in the south-eastern corner of Australia. This area, which embraces the Kosciusko National Park, is often termed the Australian Alps since, although it bears little resemblance to its more grandiose European counterpart, heavy snows are experienced for about half the year and skiing is a popular sport.

The gradual eastern approaches to these uplands have more than their fair share of rain whilst the steeper western slopes are relatively dry. The Snowy River rises near the summit of Mount Kosciusko and flows generally in a south-easterly direction before entering the sea at Orbost in Victoria. The flow of the Snowy and its tributaries is increased in the spring by the melting snows, and the key to the Snowy Mountains project lies in the utilization of these waters.

The Murray and Murrumbidgee Rivers also rise in the Snowy Mountains area

and flow westwards until, after uniting, they meet the sea near Adelaide in South Australia. These two rivers are already utilized in the most extensive irrigation system in the Commonwealth, but the waters at present available irrigate only a small portion of the Murray Valley. It follows therefore that if the flow of the Murray and Murrumbidgee Rivers can be increased, by diverting the Snowy and its tributaries, agricultural production in the Murray Valley can be increased.

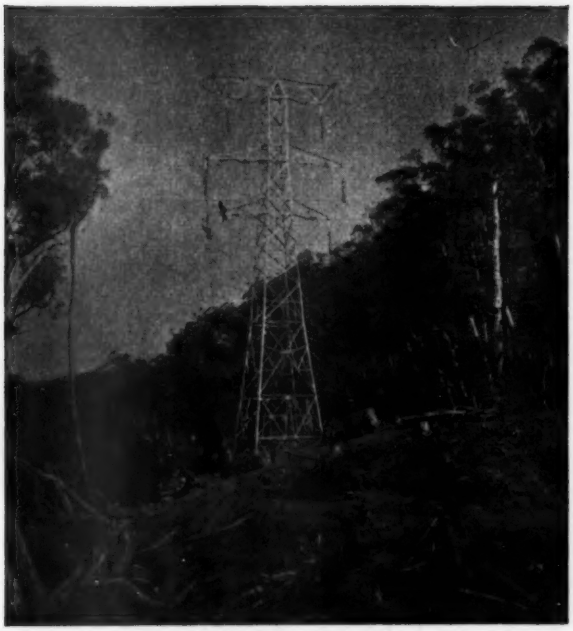
The Snowy Mountains Development

The final form of the complete Snowy Mountains scheme has been the subject of much thought over the years until the development outlined below was adopted, although it must be emphasized that investigations now in progress may cause further changes in detail. For example a proposal to divert the Murrumbidgee River from the Tantangara reservoir through a 9½-mile tunnel to the Adaminaby storage has recently been adopted and this will substantially increase the volume of the reservoir.

The essence of the scheme has not altered since its inception in 1949: the impounding of the Snowy River at Jindabyne, the Eucumbene River at Adaminaby, the Murrumbidgee River at Tantangara, and the diversion of these waters to the Murray Valley while allowing them to generate large amounts of power *en route*. It is most convenient to study the whole development as two separate entities, namely the Snowy–Tumut and the Snowy–Murray power schemes. The power stations associated with these two large projects are designated the T and M groups of stations respectively, although at a later date, no doubt, they will be individually named if the naming of the first station commissioned on the scheme (station M1B, Guthega) is to be taken as a precedent.

The voltage for the main transmission lines from the Snowy Mountains area to the load centres of Sydney and Melbourne will ultimately be 330 kV—the highest transmission voltage yet used in Australia.

The Snowy–Tumut Development. The Eucumbene River rises north of the township of Adaminaby and flows generally south, joining the Snowy River at Jindabyne. Work is now in progress on a large earth dam near Adaminaby which will trap the Eucumbene before its juncture with the Snowy. The impounded waters, which will flood the old town, will then be drawn off through a 14-mile tunnel driven in a north-westerly direction through the range to a small pondage formed behind the Tumut Pond dam on the Tumut River. These waters will initially feed stations T1 and T2, each of 320 MW installed capacity. Stations T5 (110 MW), T6 (85 MW), and T7 (50 MW) form the remaining stations on this development, the discharging waters from which ultimately reach the Murrumbidgee north of the town of Tumut.



Construction of the double-circuit steel-tower transmission line from Guthega

The Snowy–Murray Development. The damming of the Snowy River at Jindabyne and its diversion westwards to the Murray Valley, through a series of tunnels and power stations, is the main feature of this develop-

Guthega hydro-station nearing completion
The station contains two 30 MW generators.

The new town of Cabramurra in winter

ment. Subsidiary to this is the exploitation of the upper reaches of the Snowy of which Guthega power station forms a part. Jindabyne's old township will be inundated by the large reservoir formed by the dam on the Snowy. A system of tunnels and power stations, M3 (190 MW), M5 low-level (20 MW), M6 (290 MW) and M7 (910 MW), will use these waters before finally discharging them into the Swampy Plain River, which flows into the Murray.

Stations on the upper Snowy River consist of M1A (65 MW), M1B Guthega (60 MW initially and possibly 90 MW eventually), and M2 (65 MW). Some 115 MW of power will also be made available by exploiting the upper Geehi River in stations M4 and M5. Both of these subsidiary developments discharge their waters into the main diversion of the Snowy from Jindabyne to the Swampy Plain River.

Progress to Date

Power from Guthega power station first flowed into the Electricity Commission of New South Wales system in February, 1955, and was formally opened by the Commonwealth Prime Minister, Mr. R. G. Menzies, on the 23rd April, 1955. Guthega forms a very small part of the final development, but a great deal of pioneering work was necessary before work on the project could begin, such as the building, by the Snowy Mountains Hydro-Electric Authority, of a small township, named Island Bend, downstream of the power station, and a smaller settlement at the site of the power station, together with about 50 miles of roads through virgin country.

The project consists of a small dam on the upper Snowy, a $3\frac{1}{2}$-mile diversion tunnel, and the power station. Two 30 MW units are at present installed in the station and there is provision for the installation of a further generator at a later date. Transmission is at 132 kV into the New South Wales system over steel towers for the high-elevation section of the route and over wooden poles at lower altitudes. Part of the Authority's constructional power system at 66 kV is also carried over the steel-tower section.

A regional centre for the works on the upper reaches of the Tumut River has been established some 70 miles by road north-west of Cooma and named Cabramurra. Possessing its own post office, Cabramurra is now Australia's highest town, at an elevation of 4 800 ft. Accommodation is provided for some 70 families, 120 staff, and 600 industrial employees. Other smaller settlements have sprung up at convenient points for the construction of the Adaminaby dam, the Eucumbene-Tumut tunnel, Tumut Pond dam and the underground power station T1.

Latest reports from Australia state that the Eucumbene-Tumut tunnel is being driven at a rate of some 400 ft per week, the access tunnel to T1 power station is halfway to the position of the generating gallery, and the first 65-mile section of the 330 kV transmission line to Sydney is about half completed.

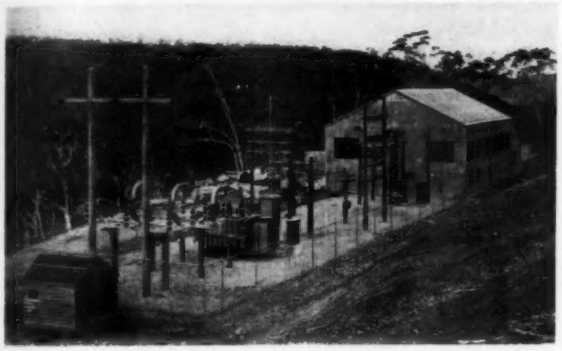
Power for Construction

Concurrently with the opening up of virgin country the Authority's 'temporary' (i.e. for a decade or so) constructional electrical power system has grown until it now consists of some 5·3 MW of Diesel generating plant, approximately 100 miles of 66 kV transmission lines, about 10 miles of 11 kV lines, and extensive l.t. reticulation lines for domestic and constructional purposes.

Power for the construction of the Guthega project was met by two local Diesel power stations which transmitted power over short 11 kV lines to the dam, tunnel, and power-station workings. This state of affairs prevailed

until the constructional power system's 66 kV supply was available at Guthega, shortly before the power station was completed.

From the start of the T1 project, however, transmitted power has been available from the New South Wales system over the 66 kV lines. In the event of a failure in transmitted supply the system can be operated by Diesel power stations sited at Cabramurra, Eucumbene Portal, and Junction Shaft (the last two places being on the route of the Eucumbene–Tumut tunnel). On occasions,



Eucumbene Portal Diesel power station

The output of 1 400 kW over a 66 kV transmission line is used for construction purposes.

with the constructional power system isolated from the New South Wales grid at Cooma, the three Diesel power stations have supplied the whole Snowy Mountains load.

Personnel

Since the Second World War there has been a steady flow of migrants to Australia and the national Press recently reported the arrival of the millionth post-war immigrant at Fremantle.* Latest statistics show that during the post-war period ending June, 1955, Australia has received 947 680 permanent new arrivals. During the same period there were 214 874 permanent departures, giving a net gain of 732 806 to the Australian population. Of the 947 680 arrivals almost half were British whilst the remainder were mainly drawn from Central and Western Europe.

A considerable proportion of these new arrivals have settled in New South Wales and many of the professional, technical, and labour force of the Snowy Mountains Authority are 'new Australians'. At one period during the construction of electrical works in the field, for example, the author was in charge of a labour force of 40 men of whom only three were Australians.

It will be appreciated that the personnel problems under such conditions are of major importance, but, happily, few real difficulties have arisen through men of many nationalities living together for months, often under severe weather conditions. The Authority provides each man, of whatever status, with a rent-free room together with communal meals at reasonable prices, staff accommodation being of a higher standard. Married life is encouraged by the provision of transportable houses built by the Authority in Cooma. The work in hand perforce dominates regional life, although amenities are encouraged on a communal basis with skiing in season and cinema shows twice a week.

* *The Times*, London, 4th November, 1955.

Future Development

By the end of 1958 it is expected that two of the four units in T1 power station will be in service from the water stored behind Tumut Pond dam. The Eucumbene–Tumut tunnel is scheduled for completion a year later and thus the waters from Adaminaby reservoir will be made available for T1. An exploratory shaft has been sunk at the site of T2 power station, and a commissioning date in 1962 for the first two units is at present envisaged.

Developments beyond this are still under review but it has been authoritatively stated that stations M6, M7, M3, T5, and T6 will probably be constructed in that order. The main consideration, however, is to complete the whole project as quickly as possible to realize the Authority's declared policy of producing power more economically than the supply authorities of N.S.W. and Victoria.

Acknowledgments

The author wishes to thank Sir William Hudson, Commissioner of the Snowy Mountains Hydro-Electric Authority, for permission to publish the information in this brief review, and to the High Commissioner for Australia at Australia House, London, for supplying latest immigration statistics.

Recreation hall at Cabramurra

HOME EVENTS

LONDON

JOINT MEETING OF THE THREE INSTITUTIONS

Training Engineers in Industry

A combined paper on *Advanced Courses for Engineers in Industry* was presented at a joint meeting of the three Institutions at The Institution of Mechanical Engineers on the 16th January, 1956. Sir George Nelson was in the chair. Parts I, II and III of the paper deal respectively with the special needs of civil, mechanical and electrical engineers, and the suggested solutions reflect these.

It soon became clear, both from the authors' views as presented in the papers and from the discussion that followed, that universities and technical colleges have an important part to play in providing post-graduate courses. Clearly, also, much has yet to be done before collaboration with industry over these courses works smoothly and effectively. Universities in general are still thinking of post-graduate courses to parallel their research programmes—courses in which industry has little part to play beyond supplying a steady stream of students. Industry on the other hand shrinks from the difficult task of releasing men for long post-graduate courses at a time of national manpower shortage and looks for the solution to short full-time courses.

The technical colleges have been very active in arranging part-time courses and evening classes on a wide variety of subjects ranging from serious courses at advanced level to descriptive technical talks on topical subjects. There is need to guard against the latter being accepted as a serious educational contribution.

Mr. H. D. Morgan, presenting Part I of the paper, stressed first the importance of 'mind-training aspects of education' and the need to avoid over-emphasis of purely vocational instruction. Referring to the young civil engineering graduate, he writes in the paper:

> He will have acquired a broad idea of the general principles of the several branches of engineering and a more detailed knowledge of the branch which he has adopted—civil engineering in this case. He will have a mathematical grounding, some knowledge of geology, materials, structures, and hydraulics; also of drawing and surveying. However, there is a notable list of subjects about which he will know very little but which occupy much of the practising engineer's time. These include preparation of reports; organization and planning of work; preparation of contract documents; economics of design; quantities and measurements; and legal and labour problems.
>
> In addition, there are associated subjects such as architecture, agriculture, and welfare for which the engineer is seldom directly responsible but which are often involved with his work.

A little later he writes:

> Apart from these gaps in his knowledge the graduate finds that in spite of lengthy training he is not yet equipped to prepare designs and contract documents for works without a great deal of supervision. If, however, his education has been successful in teaching him to think clearly, his mind will be in a receptive state and he will be eager to fill in any gap, not only through practice but also by further personal study. There is thus a need for further education as soon as the young engineer qualifies. Later the more experienced engineer, now possibly approaching middle-age, will find new techniques and methods of design appearing which were not available in his university days. He will also find that he is forgetting subjects in which he has not happened to have had any opportunity of gaining practical experience.

To meet these needs Mr. Morgan gives a list of subjects in which he suggests courses of instruction would be valuable:

Group I. Administration

1. Preparation of reports—structure and composition.
2. Contract procedure.
3. Preparation of estimates and make-up of costs.

Group II. Technical

1. Modern concrete technology.
   - (*a*) Preparation of concrete.
     - (i) Mix design.
     - (ii) Quality control.
   - (*b*) Concretes for special purposes.
     - (i) 'Zero slump' concrete.
     - (ii) Resistance to frost and abrasion.
   - (*c*) Ready-mixed concrete.
   - (*d*) Use of additives.
   - (*e*) Placing of concrete.
     - (i) Transport by skip.
     - (ii) Compressed-air placing.
     - (iii) Concrete pump.
     - (iv) Placing underwater.
     - (v) Placing in cold weather.
     - (vi) Vibration.
2. Pre-stressed concrete.
3. Welded steel structures.
4. Aluminium alloys in structural engineering.
5. Soil mechanics.

While acknowledging the excellent facilities that exist in London and other large centres for part-time and evening classes, he points out that for many young civil engineers there remain only correspondence courses and he makes a plea for universities and technical colleges to provide whole-time courses for periods varying from a few days to several weeks.

Professor G. F. Mucklow, presenting Part II of the paper and dealing mainly with mechanical engineers, resolved the problem into two parts. First, 'that of increasing, at each level, the number of young men entering the engineering industry and of providing suitable facilities for their basic education and training'. Secondly, 'that of maintaining and increasing the technical efficiency and professional ability of those actually engaged in engineering', involving both a short-term and a long-term requirement. The long-term programme is concerned with providing means by which

> . . . young engineers of particular promise should be picked out for special training, so that to their knowledge of the practical aspects of their chosen fields may be added a thorough understanding of the related fundamental scientific concepts and of the possibilities and limitations thereby dictated.

Part II is concerned mainly in emphasizing the need for industry to release young men who already possess several years' experience of industrial engineering for periods of 9–12 months for courses which comprise

> . . . formal lectures, tutorial classes, and laboratory work, the latter being designed to illustrate the treatments developed during lectures, to permit experimental confirmation of the results of mathematical analysis and theoretical argument and to afford familiarity with modern techniques of instrumentation. The general orientation should be towards the scientific approach, and the courses, although restricted to the chosen field of engineering science, should be in no way specialized in the narrow sense.

Professor Mucklow sees the universities as alone able to provide the facilities and atmosphere for advanced courses of the kind discussed. He criticizes certain of the larger firms where 'the thought has arisen that courses of the nature considered might well be conducted internally by staff members of the organization itself, some of them perhaps appointed for this special purpose'. At the same time he accuses engineering firms of remaining 'as yet unconvinced of the existence of the problem and still less of its urgency'. This is a little inconsistent. Without doubt industry sees the problem as clearly as the universities even if it cannot accept Professor Mucklow's solution as the only one of merit.

Professor Mucklow brings out a 'formidable difficulty to be overcome' before the type of course he advocates can be a success. However good the course may be, it needs the support and co-operation of employers in industry, who must sponsor the students and cover their expenses. Even then an intending student may be reluctant to attend a course requiring absence from his work for a whole year unless he is 'satisfied that his immediate seniority will not be prejudiced and that his ultimate prospects will be enhanced'.

Professor Mucklow closes with a plea for that active support and co-operation from industry which alone can produce a satisfactory number of students.

In Part III Dr. Willis Jackson gives a review of part-time and short full-time courses arranged by industry to meet its own particular needs in collaboration with the universities and technical colleges. He deals only with courses with which he has had personal contact but his experience is wide enough and varied enough to make his review comprehensive and authoritative.

He describes in detail the lecture courses organized as an integral part of graduate training in the company with which he is associated. They are first-year courses and lead in the second year to advanced engineering courses, organized in collaboration with Manchester College of Technology, in which lecturers and tutors are drawn equally from college and company staffs.

Included in this series are two-year courses in industrial administration organized again in collaboration with the Manchester College of Technology.

A scheme of post-advanced lectures in electrical and mechanical engineering set up by Manchester and District Advisory Council for Further Education is described in Section 3 of the paper.

Section 4 briefly describes the short full-time advanced courses organized by the Electrical Engineering Department of Imperial College of Science and Technology over the past six years, the subjects being:

Power system analysis.
Electrical machine analysis.
The insulation of electrical equipment.
The electrical equipment of aircraft.
The application of computers to the solution of engineering problems.
Electrical power-system engineering.

These courses varied in duration from five to ten days. As Dr. Willis Jackson says, they

> . . . provoked extremely valuable exchanges of experience and opinion, and on occasions, led to the clarification of important technical difficulties. The content of the first and third of the courses appeared subsequently in book form and is therefore available for the benefit of future students of these subjects. In the author's opinion there is much scope and need for more courses organized on these lines.

It is of interest to learn that the last of these courses, on electrical power-system engineering, was one of three months' duration. This course might easily have been spread over twelve months but for the difficulty of releasing men from industry for prolonged periods.

Dr. Jackson lays great stress on the importance of the work put in by the student himself. He says that

> . . . in the absence of considerable personal initiative and prolonged self-sustained effort by the student himself, no amount of attendance at formal lectures will ensure real understanding of the information supplied or facility with its application to new and difficult problems. Very little will be achieved if the lectures do no more than hand out information.

In presenting his part of the paper, Dr. Jackson gave much prominence to this point.

He concludes the paper with a description of staff courses that are being held within the company with which he is himself associated.

In the discussion which followed the presentation of the papers there were many speakers. Sir George Nelson closed the meeting with a warm vote of thanks to the authors.

G. S. C. L.

ORDINARY MEETINGS

Power from the Glens

Out-of-doors the view across the river was obscured by thick fog but inside the Institution Building there was a pleasantly warm, sociable atmosphere at the well-attended Ordinary Meeting on the 5th January, when Mr. A. A. Fulton read the late Mr. T. Lawrie's paper on *Highland Water Power*. The paper is a broad review of the works and interests of the North of Scotland Hydro-Electric Board. It begins with a brief outline of the Board's responsibilities and goes on to a historical review of water-power development in Scotland. For the modern works, dams must be built, tunnels cut, pipes laid, roads constructed, and electricity-supply systems provided, but while these offer many interesting engineering problems, the discussion of the paper seemed to suggest that the old water-wheels, salmon nurseries and

ladders, pleasing power-station buildings, and the unexpected reaction of a crofter to the economics of electric hay-drying had been more successful in capturing attention. Similarly the illustrations in the paper which catch the eye are a view of an aggressive-looking salmon framed in a bolted joint, and Clunie power station against a charming background of hills and trees.

Sir Charles Westlake, in opening the discussion, referred to the Board's responsibilities to the outlying consumer and recalled the successful policy of the Dumfries County Council in setting out to provide a supply for every ratepayer without guarantee as to demand. He congratulated the Board on the way in which their various works had brought out new beauties in the Highlands.

Further compliments were paid by Lord Hurcomb, who commended the Board not only on their attention to amenity and fishery matters but also on their assistance in botanical preservation. He spoke of his interest in a world-wide organization—the International Union for the Protection of Nature—which is doing all it can to ensure that the vast construction projects which are essential to modern civilization are planned with proper regard for the probable effects on natural life. For nature is a complex association of plants, soil, animals, etc., and while it is important to avoid degrading scenic beauty and to preserve fish life it is equally desirable to realize that diversion of streams, flooding of valleys, and other major works, may so upset some local balance of nature as to react far beyond the locality. He advocated consultation with a biologist early in the planning.

The audience enjoyed the liberty which Mr. J. D. Peattie took with the paper when he quoted words from the section on tunnelling:

> . . . the way in which the engineers light-heartedly start boring from both ends and invariably meet in the middle warrants a tribute of admiration. It was not always so.

He ventured to accept this as the first public tribute to the work of those officers of the C.E.A. and the Hydro-Electric Board who negotiated the joint working arrangements from the differing starting points defined by the respective Acts of Parliament.

Pumped storage was the engineering subject which received most attention, starting with Mr. T. G. N. Haldane's reference to the value of superimposing pumped storage on normal hydro-power development. After Mr. R. W. Mountain had suggested the probable use of large sets, Mr. M. Braikevitch outlined the characteristics of separate pump and turbine runners, and went on to describe the conflicting requirements of the single reversible runner. Progress in development has been made in the laboratory, and a design for low-head working was illustrated, but as Mr. Fulton pointed out in his reply high-head working introduces some further problems which will not be quickly solved.

Mr. C. M. Roberts, a civil engineer, commented on the saving in material and expense which can, in suitable circumstances, be obtained by underground tail-race and pressure-tunnel construction. It was interesting also to hear of the way in which the availability and type of labour can influence the choice of dam design—expensive labour and consequent mechanization in the United States, for example, create a preference for mass construction, while in North Italy, where skilled labour is more plentiful, the arch dam is favoured.

It was made clear from the beginning that a primary objective of the Board is to provide supplies of electricity to the consumer, but mention of electrical matters went little beyond this. Switchgear and transformers came into the discussion merely as items which, if not hidden in or behind a delectable building, could only serve to spoil the amenities. There was an almost lyrical account of the operating sequence of automatic-control equipment, but Mr. Fulton damped any resulting enthusiasm by pointing out that though the Board, by turning to automatic station control, had met the difficulty that the wives of station operators do not like living in remote places, they had found a comparable difficulty in recruiting the specialist staff necessary to maintain the gear.

There were many laudatory references to the author of the paper, whose untimely death has robbed the industry of an eminent engineer, and has removed from Scotland one who devoted himself to the development of Scotland's water-power resources and to the improvement of that country's amenities in the widest sense. It was natural to attribute the friendly and objective atmosphere of the whole meeting to the presence of the genial spirits of Mr. Lawrie and his predecessor Sir Alexander McColl, whose work and breadth of interest were so well surveyed in the paper.

The paper was sponsored by the Supply Section, and its Chairman, Mr. L. Drucquer, in moving the vote of thanks, ascribed the keen interest of the audience to the author's presentation of 'not a recital of statistics, but a simple account of the ways in which the North of Scotland Hydro-Electric Board brought the blessings of electricity to consumers in a difficult and sparsely-populated area'. F. J. L.

An Outsize Analogue Computer

*Tridac, a Large Analogue Computing Machine** was the title of the Measurement and Control Section paper presented at the Ordinary Meeting on the 1st December, 1955, at which the President took the chair. The paper was presented by two of the authors, Lt.-Cmdr. F. R. J. Spearman and Mr. J. J. Gait. Unfortunately the other two authors, Mr. A. V. Hemingway and Mr. R. W. Hynes, were abroad.

The paper describes a very large analogue computer now installed at the Royal Aircraft Establishment, Farnborough. The computer is required to solve problems connected with the controlled flight of aircraft and guided missiles, and for this purpose is required to make the calculations (many of them non-linear) in *real time*, i.e. at the same speed as the actual operations in flight, so that component parts of a guidance system can be included in the apparatus for tests. The computer is

* An article based on this paper appeared in the November, 1955, issue of the *Journal*, page 684.

sufficiently large for the whole operation of firing a missile at an aircraft target, which is detected and followed by radar, to be simulated, and for the motion of both target and missile to be displayed and recorded throughout the action.

The discussion was opened by Mr. J. F. Coales, who was involved in the early planning of the project. He raised the question of the possible use of digital computers for the solution of these very complicated problems in real time, and said that it was believed in 1948 that no digital solution was feasible. At that time it appeared that a digital computer to solve these problems would have to be a parallel-operated machine of enormous size, but it was not then expected that the necessary analogue machine would cost £750 000, employ 2 000 amplifiers and some 8 000 electronic valves and require a peak power of 600 kW. A digital machine of such magnitude might now be more satisfactory although there are some practical advantages in using an analogue machine.

Mr. Coales went on to speak of the difficulties of axis conversion, 3-axis gimbal systems, amplifier drift and analogue multipliers, mentioning that, if there was no possibility of having a 3-axis gimbal system in which components could be tested, it might be possible to effect a considerable saving by making the conversion of quantities from fixed to moving frames of reference (and vice versa) by means of integration of the rates of change of the direction cosines.

The next speaker was Monsieur F. Raymond of the Société Électronique et d'Automatisme, Paris, who spoke in French. He described a combined digital and analogue computing machine which has been built in France for the solution of particularly difficult aeronautical problems in which the velocity of roll is very high. The range of velocity to be covered is very large, and it has been arranged that the analogue computer takes care of a wide range of operation at high speed with comparatively low accuracy while the digital computer takes care of smaller changes with a high accuracy. The speed of the digital computer is such that 200 operations are calculated per second.

When Monsieur Raymond had finished speaking, an extempore translation was given by Mr. G. Ashdown.

Mr. W. R. Thomas then took up the cudgels on behalf of analogue computers for solving missile problems, pointing out that the task of programming such problems for a digital machine would be formidable even if the machine was sufficiently large to be fast enough. He said that it is flexibility and universality for all types of flight problems that have made Tridac so large, costly and power-consuming. When it is necessary to change parameters of the system frequently and get the feel of what is happening it is necessary to use analogue techniques.

Mr. C. A. A. Wass thought that although available digital machines are, for the type of problem discussed, some hundreds of times slower than real time, there is now more chance of the digital machines getting sufficiently fast than there is of the analogue machines getting more accurate, so that, if there is to be a successor to Tridac, the designers will have a more difficult task in deciding whether it should be analogue or digital.

Mr. E. C. G. Burt commented on the proper use of Tridac in the assessment of missile systems, explaining that it is only when the system is well understood as a result of simulation of the component parts that the whole system is set up on Tridac for full-scale assessment. The final output of Tridac should therefore be much more than a large quantity of numbers and graphs. It should, in fact, be a complete appreciation of the various factors which affect systems as a whole.

Mr. L. E. McAllister commented on an analogue machine for simulating large servo systems, for which purpose an analogue machine is much more convenient than a digital one. He also mentioned d.c. amplifiers without chopper-type drift-compensation, which had a drift of not more than ± 2 mV per half-hour at unit gain.

In reply Mr. Gait explained very convincingly the advantages of using a synthetic gimbal system rather than direction cosines for axis conversion; the angles of the gimbals have physical significance in the problem whereas the direction cosines have not. One of the reasons for retaining the 1 : 1 time scale (real time), is that engineers at the R.A.E. are interested in the operation of the actual control surfaces of missiles and still want to introduce parts of guidance systems into the simulator.

With regard to drift-compensated amplifiers he pointed out that, if an amplifier has to be reset every half an hour to maintain a drift voltage of less than 2 mV, it would involve resetting 4 500 amplifiers per hour, which would be a Herculean task. It was earlier commented by Mr. Thomas that in maintaining accuracy the stability of components is now a more serious problem than the drift of amplifiers.

On the subject of analogue versus digital machines for flight simulation, Mr. Gait looked forward to the day when he could enjoy the best of both worlds, by retaining the convenience of the analogue machine in having the various mathematical operations, addition, integration, multiplication and division, in convenient blocks to be connected in any way he wished, but with the high accuracy of the digital machine in the computation of the operations themselves. He congratulated Monsieur Raymond on having made some progress towards this Utopia by successfully combining digital and analogue techniques in a machine of the type described by him.

To conclude the evening a vote of thanks to the authors was proposed by the Chairman of the Measurement and Control Section, Mr. W. Bamford. J. F. C.

MEASUREMENT AND CONTROL SECTION

Old Puzzle—New Solution

At the Measurement and Control Section meeting on the 17th January, the chair was taken by Mr. H. S. Petch, in the absence of Mr. Bamford. A paper on metering is something of a stimulant to a Section that has had many

lively meetings on this subject in the past. The paper *A New Meter for the Kilovolt-Ampere-Demand Charge*, read by Mr. P. Baxter, aroused interest in an old problem, particularly as a novel solution was presented. A short review of the paper appears on page 170, and this includes a description of the new meter.

While the standard single-phase watt-hour meter satisfies the needs of most consumers purchasing a supply of electricity, there are problems connected with peak demand and power factor of the load in charging larger consumers taking 3-phase supplies; many ingenious methods of metering such circuits have been evolved.

The author pointed out that charges based on a maximum demand act as an incentive to a consumer to level out his load as well as to enable a supply authority to recover costs having some relation to the total volt-ampere capacity of the system to supply the load. To illustrate the differences that could arise in distribution costs an example was quoted of two consumers each having the same maximum demand (in kilowatts) and consuming the same number of kilowatt-hours, but with load power factors of 1 and 0·5: the second consumer needs supply equipment costing twice that needed by the first. On an energy basis both consumers would pay the same whereas some extra charge for the low power factor is justified.

Mr. D. J. Bolton, in opening the discussion, referred to difficulties in dealing with charges associated with bad power factor. In fact he said that it was surprising that Agatha Christie had not devoted some attention to it, as an unsolved mystery. He went on to describe some of the complexities of the two-part tariff system and felt that the new meter would help to simplify some of these. He also gave historical information about kilovolt-ampere- and kilowatt-demand measurement, and it was most interesting to hear about early methods on a kilovolt-ampere basis and their limitations.

Other speakers referred to difficulties in dealing with the power-factor problems of tariffs and it would seem that direct kilovolt-ampere measurement helps to simplify them.

Generally the discussion was not very critical, though the author was taken to task on his methods of compensation and lack of data on performance. Suggestions were also made to extend the use of the meter to summate several circuits. One speaker in referring to the anomalies and ambiguities that can arise from the indiscriminate use of certain definitions of apparent power (measured in kilovolt-amperes) made a plea for the solving of the fundamental problem of kilovolt-ampere measurements and tariffs based on them. He also confessed to having been a sort of midwife in assisting in the birth of several kilovolt-ampere indicators for that purpose, and his further reference to parent inventors waiting for test results from their offspring went down very well.

The author was left little time to reply to a discussion which had ranged over practically all aspects of his paper, and the meeting was closed by some excellent comments in the vote of thanks proposed by Mr. Petch. C. R.

MEASUREMENT AND CONTROL SECTION
UTILIZATION SECTION

Free Electrons in the Mill

The paper presented by Mr. S. S. Carlisle and Mr. G. W. Alderton at a joint meeting of the Measurement and Control and the Utilization Sections on the 6th December, 1955, which was entitled *The Instrumentation of a 14-inch Experimental Rolling Mill*, had—perhaps surprisingly—a wide appeal. The Chairman, Mr. W. Bamford, was able to welcome not only the President, Sir George Nelson, and members of the Utilization Section including a Vice-Chairman, Mr. H. J. Gibson, but also members of the Iron and Steel Institute.

The scope of the paper, of which a short review appears on page 171, was in some ways a microcosm of the Measurement and Control Section itself. Mr. Carlisle described the main quantities to be measured: roll force, strip tension and gauge and roll-driving torque. Each required a transducer (or pick-up), an amplifier and a 'display'. A feature of the work was the use of a standardized type of amplifier unit for each quantity. Mr. Carlisle then went further, and described the application of the same methods to automatic gauge control. All this work was done on an experimental mill, with the dual object of pioneering reliable methods for production mills, and of providing accurate control for research carried out on the mill itself.

The President opened the discussion. After expressing his pleasure at being able to make his first official visit to a meeting of the Measurement and Control Section, he proceeded to make two main points: first, that the extraordinary advance in methods of steel rolling had been made possible only by the application of electrical drives, and secondly, that instrumentation provides in this field, as in so many others, the key to future progress. 'We cannot get extra output by putting more men in, because the men are not there', but 'through instrumentation and through its proper application we can maintain and improve the economic life of the country'.

The following discussion possessed, in a way, a dual nature. Most speakers wished to comment on, or question, some point of detail, nomenclature, method or performance. All were also concerned, to an extent that made it the leitmotiv of the discussion, with what might be described as the philosophy of the use of electronics in a steel mill. Mr. W. Spence and others were sceptical of the radius-correcting potentiometer, and Mr. W. N. Jenkins suggested an alternative method. Mr. J. B. C. Robinson and Dr. Denis Taylor raised the question of magnetic amplifiers, and Mr. J. F. Coales that of transistors. Mr. Coales also gave his support to the employment of on-off controls. Dr. Syke made a strong case for the radiation gauge as an alternative method of gauge measurement, obtaining some support from Mr. T. W. Hood.

Mr. J. I. Bernard, for the Utilization Section, summarized the general feeling on the great question of whether, in fact, electronics has yet won its spurs in the

steel mill. Most speakers agreed that, at long last, electronics is accepted; maintenance engineers will now condescend to test a valve or plug in a replacement amplifier. But its triumph is short-lived, for magnetic amplifiers are with us, and transistors are just round the corner—this side of the corner, claimed Mr. Coales. Within a few years, the principles embodied in the paper will be in operation everywhere, but probably not with vacuum tubes; they will have given way to their young, stolid, untemperamental supplanters. The brief reign of the amplifier valve, whose introduction seems to many of us but a thing of yesterday, has reached its climax. It has penetrated the last stronghold of the mechanical engineer, and it is about to vanish as the physicist produces new devices.

Both authors replied to points raised in the discussion. Mr. H. J. Gibson, in proposing the vote of thanks, lent the powerful support of the Utilization Section to the employment of electronics, but characteristically pointed out the older significance of the word 'instrumentation' to musicians. When Mr. Gibson indicates the unfortunate association such a word may have with 'fiddling', only those who know him can attempt to decide whether or not he is serious. D. E.

RADIO AND TELECOMMUNICATION SECTION

Hi-Fi Multiplex

The meeting of the Radio and Telecommunication Section on the 11th January, at which Mr. R. F. Rous read his paper entitled *Pulse-Time-Modulation Terminals for Music Transmission over Radio Links*, showed how a very interesting discussion can arise from a study of a particular solution to a somewhat specialized problem. A short review appears on page 173.

A radio link for conveying a television signal does not have to meet a rigorous specification concerning linearity, and this leads to considerable difficulty if an attempt is made to carry several music-transmission channels over such a link with frequency-division multiplex. A pulse-time-modulation system was described which was developed to give the facility of three music channels and an engineer's circuit over a radio link primarily designed for television. Whilst not of universal application, the ability to exchange wide band-width for a number of very-high-quality audio channels is sometimes very useful. Details of the performance of the terminal equipment and of the complete system were given and it was clear that the apparatus was able to carry audio signals of broadcast-programme quality. Signal/noise ratio, crosstalk and harmonic distortion were all well within the specification which had been laid down.

The discussion was opened by Dr. A. R. A. Rendall, whose contributions were of considerable interest because they expressed views of a possible user. Many interesting points were raised in the ensuing discussion. An example was the question of whether pulse-time modulation was suitable with long-distance propagation by scatter. An entirely different point was made by Mr. J. Moir, when he suggested that as distortion requirements are more critical for a certain range of audio frequency liberties might be taken at other frequencies, for instance at the low frequencies. The discussion had its lighter moments and an equation in the paper with a dubious decibel gave Mr. B. B. Jacobson a chance for a friendly jibe at the author.

The nature of the discussion showed that Mr. Rous had presented the paper in just the right way, so that the intimate electrical detail had been left to those who wished to study the paper closely. His summing-up, too, was equally good, and he dealt with all the points raised. A. J. B.

UTILIZATION SECTION

The Annual Dinner-Dance of the Utilization Section was held at the Café Royal on the 18th January, 1956, under the chairmanship of Mr. D. B. Hogg, Chairman of the Section. The total attendance was 152, and the Section were pleased to welcome as their guests the President and Lady Nelson, the Chairman of the Supply Section and Mrs. Drucquer, and the Chairman of the Radio and Telecommunication Section and Mrs. Stanesby.

LONDON GRADUATES AND STUDENTS SECTION

The Young Trophy

Each year the London Graduates and Students Sections of The Institutions of Civil, of Mechanical, and of Electrical Engineers arrange a sporting competition for a Trophy presented in 1934 by Mr. H. T. Young, a Past-President, the object of which is to cultivate and maintain friendship between members of the Sections. The sports include Cricket, Lawn Tennis, Rifle Shooting, Squash Rackets and Table Tennis.

Our Students and Graduates have not won the Trophy for a number of years, and it is hoped that this session more members of the London Section will come forward to support the Committee in their efforts to regain it.

The standard in the games is not exacting, and all players, whether good, bad or indifferent, will therefore be welcomed. Names should be sent to the Young Trophy Secretary, Mr. A. T. Brading, 36 Cold Blow Crescent, Bexley, Kent.

EDINBURGH AND GLASGOW

SCOTTISH CENTRE

The Graham Clark Lecture

The Scottish Centre was honoured by having, in Edinburgh on the 17th January, 1956, the first presentation outside London of the Graham Clark Lecture by Sir Harold Hartley. The interest of the subject, *The Engineer's*

Contribution to the Conservation of Natural Resources, and the eminence of the author secured a large attendance of members of The Institutions of Civil, of Mechanical and of Electrical Engineers. In his opening remarks Sir Harold referred to the work and influence of Graham Clark, for seventeen years the Secretary of The Institution of Civil Engineers, in fostering the idea of the essential unity of the engineering profession and in securing co-operation between the three major Institutions. Sir Harold then gave a delightful and almost informal summary of the lecture as delivered in London, and already published [*Journal*, 1955, Vol. I (New Series), p. 553], embellished by numerous anecdotes drawn from his vast experience of engineering undertakings throughout the world. Those present will surely remember this lecture as an outstanding event in the history of the Scottish Centre and the South-East Scotland Sub-Centre.

Brightness Levels for Colour Television

On the 31st January and the 1st February, in Edinburgh and Glasgow respectively, Dr. G. N. Patchett gave an informal lecture on *Colour Television*. The lecture was, in fact, almost two lectures in one, the first part dealing with the theory of colour, amplified by some striking demonstrations, and the second with the principles of various colour-television systems, illustrated by coloured lantern slides showing results obtained. When introducing the lecturer in Edinburgh, the Chairman mentioned that the author had several versions of the lecture available, ranging upwards from one suitable for those of 8–12 years of age; after surveying the audience Dr. Patchett delivered a version that was completely understood and thoroughly enjoyed by the 70 members present.

In Glasgow he gave a somewhat different version.

In both cities, however, Dr. Patchett was complimented on the exceptional clarity with which he had presented his ideas and on the results that he had obtained on apparatus built in his college laboratories.

Social Events

In Edinburgh the joint dance with The Institution of Civil Engineers, which seems to have become established as an annual event, was held in the Charlotte Rooms on the 2nd February. About 120 members and guests were present and spent an even more enjoyable evening, if that were possible, than on previous occasions.

The usual Spring Meeting of the Centre was not held last year owing to The Institution's Summer Visit to Scotland, but this year it is again being organized. Although a number of suggestions were examined, the Committee decided that no better or more beautiful place could be found for it than Pitlochry, and arrangements have again been made with the Atholl Palace hotel for the week-end from the 18th to the 21st May.

E. O. T.

OXFORD

DISTRICT MEETING

An informal meeting was held on the evening of the 11th January, 1956, at which members and guests heard a paper entitled *Atomic Energy Programme* read by Mr. R. A. Peddie, of the Nuclear Power Branch of the Central Electricity Authority.

The paper began with a survey of the probable future power demands of this country up to the year 1980. It was anticipated that 19% of the total electrical-power demand in 1965, rising to 51% in 1980, would have to be provided by other than home-produced coal, so that the possibilities of using imported fossil fuel or nuclear heat sources to make up the deficit would have to be considered.

Mr. Peddie next showed that nuclear-reactor power plant could be an economic proposition, but this was dependent on running such plant at an assumed annual load factor of 75%. Referring to the White Paper on *A Programme of Nuclear Power*, he said that progress was envisaged in two stages; first, the construction of a number of gas-cooled graphite-moderated reactors, and later the construction of more advanced types utilizing some form of liquid cooling, their design to be based on the experience then obtained.

Mr. Peddie concluded his paper with an outline of the problems of reactor design, including safety, heat exchange (using water or liquid metals), radiation shielding and stability of operation.

After an interval for refreshments, Mr. Peddie was assailed by numerous questions, some obviously from members of the audience employed at the Atomic Energy Research Establishment, Harwell. The convener, Mr. J. L. Taylor, who was in the chair, called on Mr. J. E. Bown to propose a vote of thanks to Mr. Peddie for his interesting paper, and this was enthusiastically supported.

G. Z.

SHEFFIELD AND SCUNTHORPE

SHEFFIELD SUB-CENTRE

A Full Programme

The programme for the session opened on the 19th October, 1956, when the new Chairman, Mr. W. Rewcastle, gave his Address on *Some Problems associated with the Development of the Primary Distribution System in Sheffield*. This paper described the development of the 33 kV system in the Sheffield area from 1934 up to the present day, and included some interesting details of the experiments carried out by the Yorkshire Electricity Board on the conductivity of the earth and on the rating of cables laid in the ground.

At this meeting it was announced that a Students' Premium had been granted to Mr. T. E. Broadbent for his paper *The Tripping of Impulse Generators*, and it was also announced that the Sub-Centre Students' Paper Grant had been given to Mr. H. Gill for his paper *Resistance Strain Gauges*. Copies of *The History of The Institution* were presented to retiring members of the Sub-Centre Committee.

On the 26th October we had our annual meeting at

Scunthorpe: Mr. J. Ashmore gave a lecture on *Repairing Electrical Plant*, which was greatly appreciated by members in the Scunthorpe area.

A smaller version of a Faraday Lecture was heard on the 16th November when Mr. R. V. Mills gave a paper on *New Lamps, New Uses, and New Lighting Techniques*. We have never had quite such a display of equipment at a normal meeting before, and many excellent demonstrations were carried out by Mr. Mills's assistant. The demonstrations of the colour-rendering properties of various lamps and of the effect of temperature on the ordinary sodium-vapour lamp were exceptionally interesting.

There was a full house on the 14th December for the paper by Mr. J. A. Broughall and Mr. K. J. Cook on *The Electrification of the Manchester, Sheffield and Wath Lines, Eastern and London Midland Regions, British Railways*. Unfortunately the usual large room at the Grand Hotel was not available, and as this paper was so popular many members had to stand. As far as can be ascertained over 160 members and visitors were present, and there was a very lively discussion ranging from the possible future use of high-voltage single-phase 50 c/s supply for electric traction to the reasons for the slow adoption of vacuum braking on British Railways goods wagons. The Chairman apologized to the meeting for the crush, but even the usual large room would not have provided seats for all the people at this particular meeting. Some two years ago, when we had a paper on *Colour Television* the same problem arose, and, although over 150 people were admitted, some 30 members had to be turned away.

On the 18th January Mr. A. O. Johnson read the paper, by himself and Mr. N. F. Marsh, on *The Standardization of Retail Electricity Tariffs*. This naturally caused a brisk discussion from members representing large organizations which have to negotiate tariffs with the various Electricity Boards to suffering householders whose quarterly electricity bills seem to be growing year by year. One member suggested that electricity should be sold on a flat rate to all, like bread, margarine or cigarettes, but Mr. Johnson eventually appeared to convince most of the members present that the charges for electricity in general were fair.

The Annual Dinner-Dance will be held on the 6th April in the Royal Victoria Hotel, Sheffield, and we ask members who have not already applied for tickets to do so immediately to avoid disappointment. G. G. N.

WALES

WEST WALES (SWANSEA) SUB-CENTRE

The first Ordinary Meeting of the session was held on the 13th October, 1955. The new Chairman, Mr. J. H. Groocock, after welcoming two new Corporate Members, gave his Address entitled *The Utilization of Electricity in the Iron and Steel Industry*. He first dealt with supply and distribution and referred to the economic advantages of generating electricity by employing waste gases available in the industry. Concerning machines and control gear, he stressed the rough treatment to which a motor may be subjected, involving both overloading and shock loading. He outlined the particular problems associated with blooming- and finishing-mill motors. Mention was made of blended lighting for internal installation. In marshalling yards the use of towers provides a good standard of lighting over a large area. Dealing with communication, Mr. Groocock referred to radio control of locomotive-shunting operations, and of carrier-frequency communication with crane drivers in high bays using transmission over the down-shop leads.

There were 98 persons present at the meeting, a figure which probably constitutes a record for the Sub-Centre.

At the second Ordinary Meeting, held on the 10th November, Mr. H. W. Wolff and Mr. T. G. F. Atherton presented their paper entitled, *Design, Performance and Application of Miniature Circuit-Breakers*. The authors were subjected to a certain amount of attack in the discussion which followed, but were well able to deal with all the points raised.

The Annual Dinner and Dance were held on the 11th November at the Osborne Hotel, Langland Bay. Mr. W. F. Cartwright, who proposed the toast of 'The Institution', spoke on the part played by the electrical engineer in the steel industry. He mentioned the mythical belief in some quarters that automation began and ended with the magic eye. He referred to a few of the more recent applications of electronics in the industry, and the part played by The Institution in the technical developments of to-day. Mr. T. G. Dash, Chairman of the Western Centre, replied to the toast. Mr. G. D. Curtis, who proposed the toast of 'Our Guests', spoke of Mr. Cartwright's recent visit to Russia, and expressed surprise that he had not been able to utilize the Iron Curtain as scrap material. Mr. B. Dougal replied on behalf of the guests. The toast of 'The Chairman' was ably proposed by Mr. J. L. Griffiths. The Mayor of Swansea, Councillor Percy Morris, expressed his appreciation of the work being done by the electrical profession in aiding the development of industry in the neighbourhood.

A District Meeting was held in the Stepney Hotel at Llanelly on the 22nd November, when Mr. T. B. Rolls and Mr. E. C. Slater presented their paper entitled *Electrical Distribution in an Iron and Steel Works*. The paper was such an attraction that numbers far exceeded expectation, and difficulty was experienced in providing seating accommodation in the space available. The discussion which followed was highly successful, largely because of its informal nature, and it touched on a wide range of topics associated with the industry.

At an Ordinary Meeting on the 8th December a paper entitled *Thermionic Valves of Improved Quality for Government and Industrial Purposes*, by E. G. Rowe, P. Welch and W. W. Wright, was read by Mr. Wright.

R. F. D.

A REVIEW *of the Proceedings, Parts A and B*

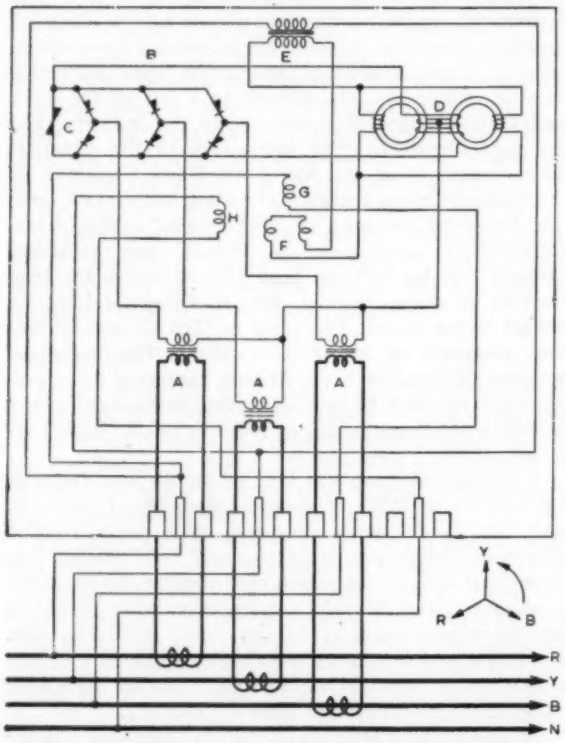
SHORT REVIEWS OF PAPERS

On the following pages are some brief articles based on, and written by the authors of, current Institution papers (including Graduates and Students Section papers). The authors have been asked to make these articles, so far as possible, of appeal to electrical engineers who have no specialized knowledge of the subjects, and the content of the articles is not necessarily confined to the subject-matter of the original papers.

Apparent-Energy Meter

A short review of a Measurement and Control Section paper (No. 1927) entitled 'A New Meter for the Kilovolt-Ampere-Demand Charge', by P. Baxter, Associate Member. The paper was published individually in November, 1955, and it will be republished in Part A of the Proceedings.

CONSUMERS WHO TAKE A THREE-PHASE LOAD FROM A three-phase system are encouraged to ensure that their load is reasonably balanced and, by the application of suitable tariffs, to maintain high values of power factor and load factor. Such tariffs include maximum-demand charges, which are based on the heaviest load delivered during any one time interval (usually of 30 min duration). When the load is measured in kilowatts, charges are usually adjusted according to a calculated value of power factor. Unfortunately, unless loads are reasonably balanced this value is difficult to understand, and adoption of a kilovolt-ampere basis for maximum-demand charges simplifies the application of industrial tariffs.



1 *Circuit diagram of apparent-energy integrating meter*

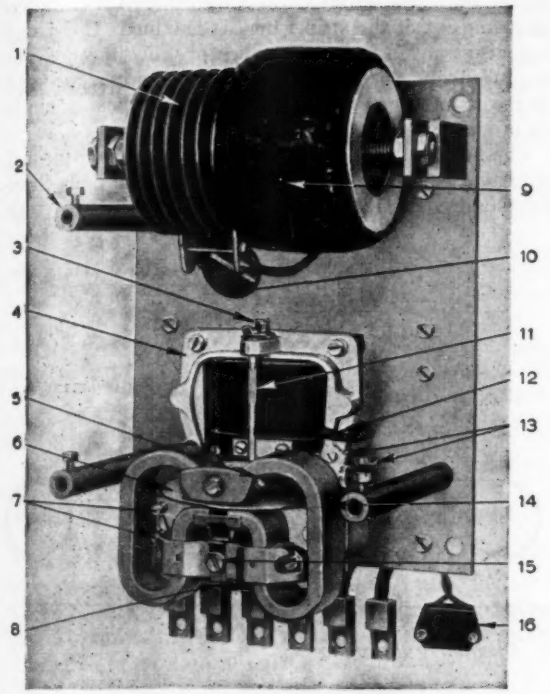
A. Auxiliary current-transformers.
B. 3-phase rectifier.
C. Metrosil unit.
D. Transductor.
E. Auxiliary voltage-transformer.
F. Meter current-coil.
G. Meter voltage-coil.
H. Synchronous motor.

Maximum demand for tariff purposes is usually measured by a Merz type of indicator which requires an integrating meter for its operation. Although the induction-type integrating meter has existed for the measurement of energy, there has, until recently, been no equivalent meter for apparent energy, but such a meter is now available.

The new meter, a circuit diagram of which is given in Fig. 1, employs an induction element F-G, a three-phase metal rectifier B and a transductor or d.c. transformer D. The induction element differs only slightly from those which are used in energy meters. Its current coil is energized from the low-voltage secondary winding of a voltage transformer E through the a.c. windings of the transductor. The voltage-transformer primary winding and also the meter voltage-coil are wound for connection to the supply voltage or to a mains voltage-transformer. The control, or primary, winding of the transductor carries direct current from the rectifier, which is fed from the low-current secondary windings of three current-transformers A, which have their primary windings connected either into the three main lines or to the secondaries of mains current-transformers.

The meter element, the four auxiliary transformers, the rectifier and the transductor are mounted with a Merz-type maximum-demand indicator into an ordinary polyphase-meter case, the internal arrangement of which is shown in Fig. 2.

The transductor comprises two strip-wound nickel-alloy ring cores, each of which carries an a.c. winding with the primary, or d.c. control winding, embracing both cores. The two a.c. windings connected together become the secondary winding, and rectified alternating current of variable power-factor passing through the

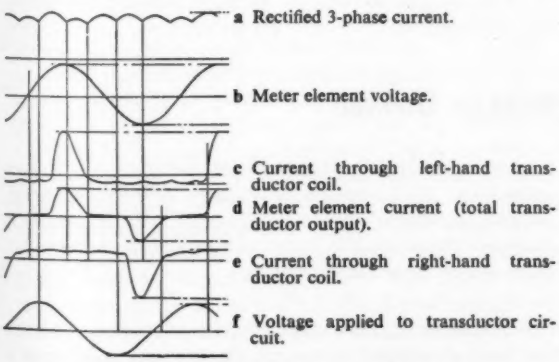


2 *Internal arrangement of meter components*

1. 3-phase metal rectifier.
2. Sockets for indicator mechanism.
3. Spring clamp for top bearing.
4. Die-cast meter frame.
5. Locking screw for low-load adjustment.
6. Aluminium disc.
7. Coarse speed adjustment moving brake-magnet system.
8. Micrometer speed adjustment by magnetic shunt across brake-magnetic poles.
9. Transductor.
10. Metrosil disc.
11. Pinion drive to indicator mechanism.
12. Low-load compensator.
13. Low-load adjustment.
14. Twin brake-magnets.
15. Locking screw for micrometer speed adjustment.
16. Socket for resetting-mechanism motor.

(The transformers are mounted on the back of the chassis.)

primary is converted, in the secondary, to alternating current with its phase fixed in relation to an alternating voltage.


a Rectified 3-phase current.
b Meter element voltage.
c Current through left-hand transductor coil.
d Meter element current (total transductor output).
e Current through right-hand transductor coil.
f Voltage applied to transductor circuit.

3 *Operation of meter components on 100% load*

Oscillograph tests have been carried out and Fig. 3 shows phase relationships within the meter. The transductor secondary-current pulse (*d*) is the sum of two currents (*c*) and (*e*), one passing through the winding of one ring core and the other through the winding of the other ring core. Traces of these currents in the diagrams show that although the ripple in the primary-current (*a*) is present in each of the two currents (*c*) and (*e*), it is non-existent in the total secondary current (*d*).

The transductor secondary current, which passes through the meter-element current coil, is a measure of the total current of the system, and is always in phase with the meter-element voltage (*b*). Integration therefore takes place at a rate corresponding to the total three-phase apparent power in volt-amperes.

The new meter is produced to meet, where applicable, the British Standard for commercial meters. A typical meter is accurate to within $\pm 1 \cdot 5\%$ over a load range of 5–125%, and the meters now in service, which number over a thousand (some of which have been working for more than five years), have proved to be as reliable as induction-type energy meters. 621.317.782.2

An Experimental Rolling Mill

A short review of a Measurement and Control Section paper (No. 1933) entitled 'The Instrumentation of a 14-inch Experimental Rolling Mill', by S. S. Carlisle, M.Sc., Associate Member, and G. W. Alderton, B.Sc. The paper was published individually in November, 1955, and it will be republished in Part B of the Proceedings.

THE EQUIPMENT IN THE MECHANICAL WORKING SHOP AT the British Iron and Steel Research Association's laboratories at Sheffield includes a 14-inch high-speed reversible cold-strip mill for research on rolling. This mill has been equipped with instruments which provide both a visual display and a continuous record of the main variables, namely the roll force (at each side of the mill), the tension on the strip at both front and back, and the strip gauge. The scheme of instrumentation has been designed to demonstrate the latest developments in the technique of mill measurement, so providing a model on which industrial applications might be based. The designs of the circuits and items of electrical equipment have been unified to make them easier to manufacture on a commercial scale and to make maintenance easy.

The mill is also equipped for carrying out research on various systems of automatic gauge control which are being developed.

Electrical resistance strain gauges provide the sources for all three measurements (roll force, strip tension, and strip gauge). All the indicators operate on the automatic potentiometer principle. The signal from the strain-gauge bridge is compared with another signal from a linear potentiometer, and any difference between the two is

amplified; this amplified signal is fed to a servo motor coupled to the potentiometer, which is adjusted automatically until the balance point is reached. The position of the potentiometer arm thus gives a continuous indication of the amount by which the resistance strain-gauge bridge is out of balance. With this system, the calibration is independent of the gain of the electronic amplifier used. The output is sufficient to operate a large and easily read pointer—an important requirement in an industrial installation. The a.c. supply to each bridge is at a frequency of 400 c/s.

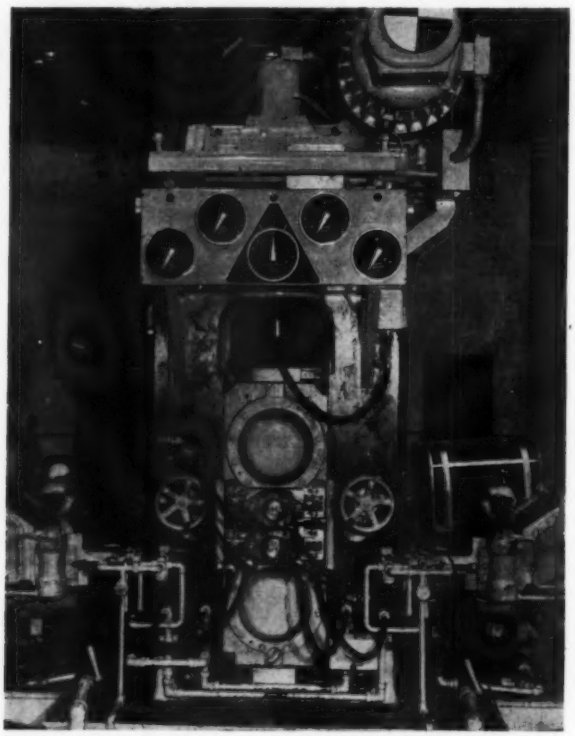
Roll force is measured by electrical resistance strain gauges fitted to steel load cylinders located under the mill screws. The strip tension is obtained by measuring the torque in the coiler shaft. A correction has to be made for the radius of the coil, and a second potentiometer is used to reduce the output from the resetting potentiometer accordingly.

The gauge of the strip is measured continuously by using the principle of the B.I.S.R.A. gaugemeter. When the strip is introduced into the gap between the rolls of a mill, the mill housing, rolls and screw are deformed elastically. Therefore, if the screw setting remains unchanged, the variation in the roll force gives a measure of the variation in the gauge of the strip. By combining the signal from the roll-force meter with a signal representing the screw setting (from a transducer), an absolute measurement of the strip gauge is obtained. The gaugemeter is arranged so that the indicator shows the deviation in gauge from a nominal value. A servo loop is included, by means of which the gauge-deviation indicator can be set automatically at zero by pressing a button.

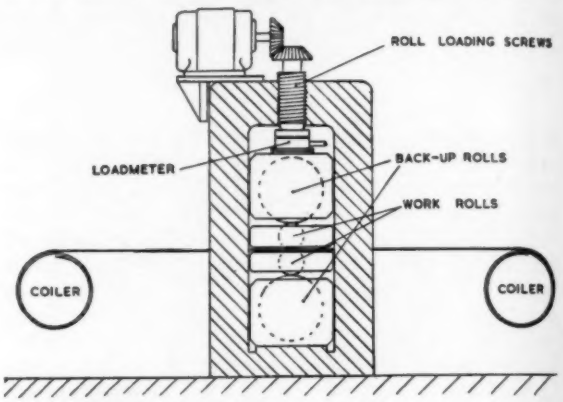
The pointers of the indicator dials are driven through reduction gearing by servo motors, and the dials themselves are mounted on the mill housing. The gauge indicator is calibrated for the range $\pm 0{\cdot}005$ in, the loadmeter scales have ranges permitting measurements from 0 to 150 tons and the tension meters measure from 0 to 5 tons. The large and clearly marked dials enable the operators to make full use of the instruments. It has been noticed that during normal running much more attention is paid to the instrument dials on this mill than to the moving-coil meters with which other experimental mills were equipped.

The roll-force and strip-tension measurements are accurate to within about $\pm 0{\cdot}2\%$, and the gaugemeter has an accuracy of $\pm 0{\cdot}001$ in. under normal rolling conditions. Experiments have been done on a simple system of automatic gauge control using the gauge deviation indicator to switch the screw-down motors on and off. This system shows considerable promise for industrial application.

621.317.7 : 621.398 : 621–5 : 621.771



1 *Experimental 14-inch four-high cold rolling mill, fully instrumented for automatic gauge control*



2 *Diagram of the rolling mill*

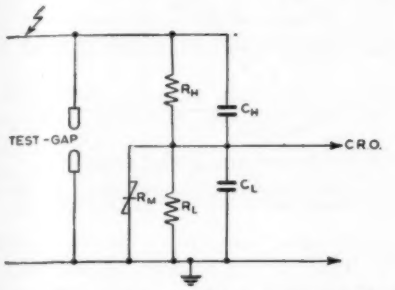
Voltage Divider

A short review of a Measurement and Control Section paper (No. 1945) entitled 'A Voltage Divider containing a Non-Linear Unit', by L. L. Alston, Ph.D., B.Sc.(Eng.), Associate Member. The paper was published in February, 1956, in Part A of the Proceedings.

THE DIAGRAM ILLUSTRATES A VOLTAGE DIVIDER WHICH has been developed to record the burning voltage of a discharge initiated by a high-voltage sparkover. R_H and

R_L constitute a conventional resistance divider; the stray capacitances associated with it can be represented by C_H and C_L over the time range considered. R_M is a silicon-carbide non-ohmic resistor, chosen so that it tends to an open-circuit when the discharge is burning, but limits the voltage at the oscillograph to a safe value just before sparkover, when the voltage across the divider is high.

The main limitation of this method is due to charges which accumulate on the stray capacitances just before



The voltage divider connected across a test-gap

flashover, and introduce a recording error for a time of the order of $R_H R_L(C_H + C_L)/(R_H + R_L)$ after flashover. Subsequently, the error introduced by the stray capacitances reduces to that due to their effect on the ohmic divider as in the conventional case.

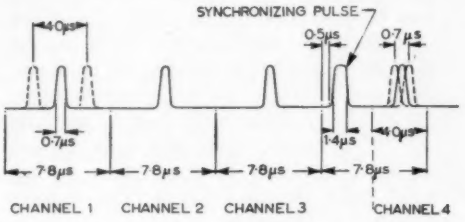
The construction of resistance dividers is usually such that the error which occurs just after flashover is insignificant when events lasting for more than 10^{-4} sec are recorded. For quicker events, that error could be eliminated by designing the divider so that the charges on C_L and C_H neutralize at flashover. 621.317.72 : 621.316.722.4

Pulse-Time-Modulation Transmission

A short review of a Radio and Telecommunication Section paper (No. 1900) entitled 'Pulse-Time-Modulation Terminals for Music Transmission over Radio Links', by R. F. Rous, B.Sc. The paper was published individually in September, 1955, and it will be republished in Part B of the Proceedings.

THE MULTIPLEX EQUIPMENT DESCRIBED IN THE PAPER IS probably the first engineered system which will transmit and receive several programme signals using pulse time modulation (p.t.m.). The terminals are intended to be used with a super-high-frequency beam radio link designed to carry television signals. The use of pulse time modulation allows three high-quality programme transmissions to be sent over a radio link which would not give adequate performance with other multiplex forms such as frequency division. The performance recommendations of the C.C.I.F. for normal programme circuits have been adopted with minor improvements in the performance specification of the terminals. Adequate signal/noise ratios in the programme circuits are achieved with the radio link operating over a 25-mile path. A margin of 20 dB is allowed for fading of the radio signal.

It can be shown that the distortion, crosstalk, and signal/noise ratios in the programme circuits are related



The multiplexed pulse train

to the pulse repetition frequency, the pulse shape and the pulse-time-modulation depth, and the values of these parameters must be chosen with care. The pulse characteristics are given in the diagram, which shows the multiplex pulse signal that appears at the output of the p.t.m. transmitter.

The terminals of the p.t.m. equipment provide three high-quality channels and a spare channel for emergency operation or engineer's use. In the transmitting terminal the programme signals are applied to four channel modulators which obtain their timing waveforms from a common unit. The p.t.m. signals produced in the modulator panels are combined with a synchronizing pulse train to form the multiplex signal. In the receiving terminal a timing-pulse unit is controlled by the received synchronizing pulses. This unit generates timing waveforms for the operation of four channel-demodulator units which are supplied with the received p.t.m. signal. The audio-frequency signals obtained by the demodulation process are conveyed to four amplifiers which pass the programme transmissions to line.

621.376.54 : 621.396.65

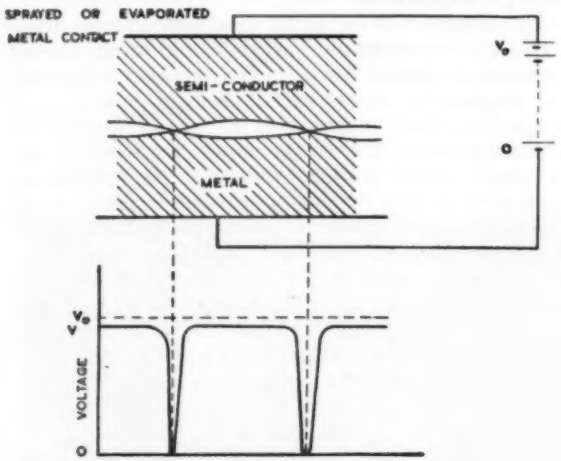
Johnsen-Rahbek Effect

A short review of a Measurement and Control Section paper (No. 2007) entitled 'Some Theoretical and Practical Considerations of the Johnsen–Rahbek Effect', by Miss A. D. Stuckes, M.A., A.Inst.P. The paper is published in March, 1956, in Part B of the Proceedings.

About 1917 two Danish scientists A. Johnsen and K. Rahbek observed that on applying 400 volts between plane and polished plates of lithographic stone and metal in contact with each other a force equivalent to 50 g/cm^2 was developed between them. The force was dependent on the direction of the current flowing and became extremely small if the lithographic stone was dried. Similar results were obtained with a large number of

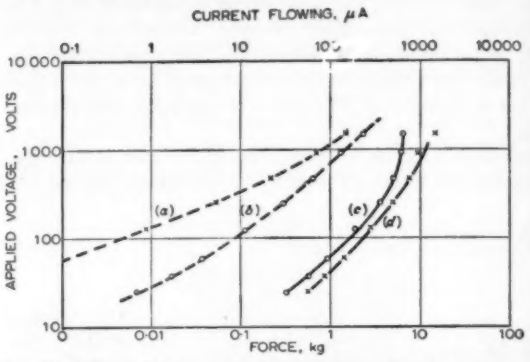
materials that would now be classed as ionic semi-conductors. High-resistance electronic semi-conductors give the same effect. The forces obtained are virtually independent of the direction of current flow and of the presence of moisture, and since the surfaces can be polished to within optical limits much greater forces can be obtained. Many metal oxides can be produced in the form of sintered ceramics with an electronic conductivity which can be varied over a wide range by slightly varying the composition. A convenient one is magnesium orthotitanate, which can be produced as a hard dense body with a resistivity of the order of 10^7 ohm-cm. With 400 volts applied between the polished surfaces of magnesium orthotitanate and metal (each flat to $2{\cdot}5\times10^{-5}$ cm) a force equivalent to 3 kg/cm^2 is developed.

Evidence indicates that this force is electrostatic. It is well known that even surfaces which are flat to within optical limits touch at only a few small areas and elsewhere are separated by a gap of about half a micron. Hence the current flow is constricted through these small areas giving rise to a contact resistance which is very much greater than the resistance of the semi-conductor. Consequently, as shown in Fig. 1, there is a rapid change



1 *Potential distribution at surface of semi-conductor*

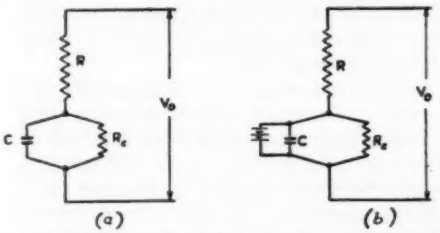
of potential in the neighbourhood of the contact points so that there is a potential difference across the air-gap only a little less than the applied voltage. This suggests that the force should be directly proportional to the square of the applied voltage. However, the force cannot increase indefinitely with increase in voltage but will become constant because the field in the gap must ultimately be limited to that at which field emission occurs, usually taken to be about 10^7 volts/cm. This will occur at a few hundred volts with surfaces flat to about one-quarter of a micron. The theoretical limit to the force available is therefore equivalent to about 30 kg/cm^2, but if (as seems likely) field emission on surfaces contaminated by the atmosphere occurs at lower field strengths, this limit will also be lowered. Experimental voltage/force curves are shown in Fig. 2.



2 *Variation of force and current with applied potential*

(*a*) Current/voltage, metal negative. (*b*) Current/voltage, metal positive. (*c*) Force/voltage, metal positive. (*d*) Force/voltage, metal negative.

The Johnsen–Rahbek effect may be represented by the equivalent circuit shown in Fig. 3(*a*) where C is the



3 *Equivalent circuits for the Johnsen–Rahbek effect*

capacitance formed by the gap between the surfaces and R_c represents the constriction resistance of the contact points. At low voltages R_c will be very much larger than R, the resistance of the semi-conductor. Ultimately, as the voltage is increased and field emission occurs, the equivalent circuit becomes that of Fig. 3(*b*). There is a time-lag associated with the build-up of the electrostatic force, and the time-constant CR may be taken as a simple index of it.

The much larger forces now obtainable suggested that the effect might be applied in an electrostatic clutch. The rapid time-response and low power-consumption appeared to be advantageous although it seemed likely that it would be suitable only for on–off applications. However, life tests have shown that such a device is not sufficiently consistent in behaviour, and it has been concluded that for a reasonable power transmission the inconsistency would be overcome only by control of the surface configurations to impractical limits.

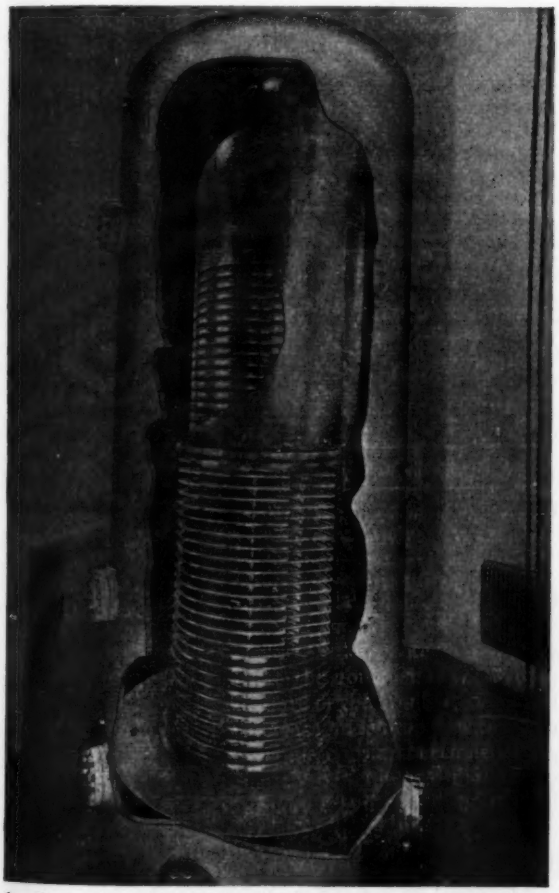
More practical applications probably lie in the use of the direct force of attraction between non-rotating surfaces. This force cannot be used to bring the surfaces

together from some distance apart, but if they are placed together (e.g. by some mechanical, hydraulic or pneumatic device) the application of a suitable voltage will continue to hold them together. Experiments on a device of this nature have shown that it continues to respond to a signal voltage for a few million operations without damage to the polished surfaces. It has also been shown that the effect can be utilized in a similar fashion in the design of a valve to control rate of gas-flow in accordance with electric signals. 537.211:621.315.59:621.838.3

An Electrostatic Particle Accelerator

A short review of a Measurement and Control Section paper (No. 1869) with the above title, by D. R. Chick, B.Sc., Member, and D. P. R. Petrie, M.Sc. The paper was published individually in July, 1955, and it is republished this month in Part B of the Proceedings.

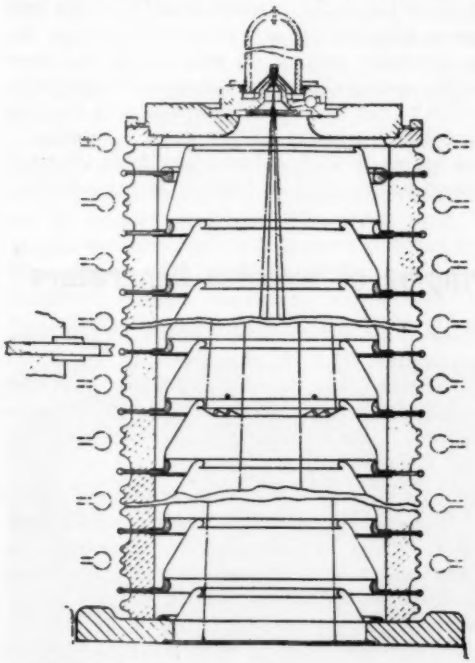
A HIGH-VOLTAGE POSITIVE-ION ACCELERATOR HAS BEEN built for nuclear research up to 4MeV. The generator, illustrated in the composite photograph, Fig. 1, is of the Van de Graaff type in which charge is sprayed by corona on to a moving insulated belt and removed at the h.v. terminal. With its evacuated accelerating tube, it operates in a pressure tank filled with a mixture of 90% nitrogen and 10% Freon by volume, at 150 lb/in², to provide adequate insulation.



1 *Composite photograph showing generator stack, high-voltage terminal, intermediate shield, and tank*

The generator consists of a stack of metal plates, insulated from one another, terminating in the h.v. dome which houses the upper belt pulley and charge-stripping equipment and the ion source and the equipment associated therewith. The potential is uniformly graded down the stack by a chain of resistor elements with a total resistance of 32000 megohms.

The accelerator tube, 9ft long, is composed of 43 porcelain rings alternating with steel discs, which hold the internal electrode spinnings. The assembly is shown in section in Fig. 2. Stainless-steel electrodes are used,



2 *The accelerator-tube design*

connected to the stack plates through a resistance. The tube has had a satisfactory life of about 1500 hours.

Since the generator is a constant-current source, the potential can be controlled by varying the current load. This is done, with a quick response, by modulating an electron beam from a gun at the base of the tube. The electrons are accelerated in the same vacuum tube as the positive ions and act as a load on the generator.

For accurate measurement of voltage, a well-focused proton beam is accelerated and its energy measured by deflection in an electrostatic analyser of high precision. The voltage is stabilized within 1% by a servo-loop

between the generating voltmeter and the electron gun, and within one part in 1 200 or better by a servo-loop between the electrostatic analyser and the electron gun.

Remote control and metering of the ion-source equipment within the h.v. terminal are effected by means of modulated light beams passing both up and down the stack. The telemetering facility has made possible the measurement of certain currents within the top terminal which has thrown light on the behaviour of the generator. Significant currents pass to earth through the gas itself, owing partly to corona and partly to ionization from X-rays which arise from the anode end of the tube whenever the tube is passing current. The ionization current leaving the top terminal and that arriving at the tank have been measured. The current entering the tube has also been measured, and it is found that tube conduction, X-rays and gas conduction all set in at the same voltage, usually about 2·3 MV.

The effects of the radial currents must be taken into account when inferring the generator voltage from the generating voltmeter reading. In this way it has been shown that the peak-performance voltage of the generator alone is 5·5 MV, and that of the generator with the tube installed is 3·8 MV, whether the ion beam is running or not. Proton beams up to 3·25 MeV have been obtained with an energy stability of 1 in 1 200. 621.384.6 : 621.319.3

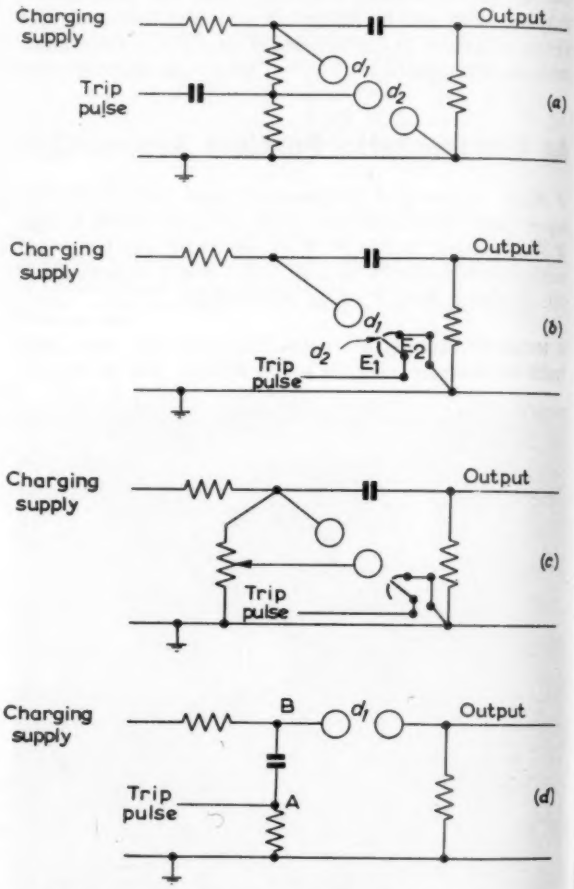
The Tripping of Impulse Generators

A short review of a Graduates and Students Section paper with the above title, by T. E. Broadbent, M.Sc., Ph.D., Graduate. The paper was awarded a Students' Premium by the Council, and a long abstract of it was published in December, 1955, in the Students' Quarterly Journal.

A HIGH-VOLTAGE IMPULSE GENERATOR IS ONE IN WHICH a number of condensers are charged in parallel and discharged suddenly in series, using spark-gaps as switches. The output voltage equals the charging voltage multiplied by the number of condensers.

The process by which the spark-gaps in an impulse generator are fired (i.e. made to break down) to produce an output voltage, is known as the *tripping* of the impulse generator. An impulse generator can be tripped (or *triggered*) in two ways. The first method, known as *uncontrolled tripping* or *self-tripping*, is to reduce the impulse generator spark-gap lengths until breakdown occurs in one spark-gap. This causes all the other gaps to break down in rapid succession and the impulse is produced. The alternative system, known as *controlled tripping*, is to keep the gap lengths constant and to initiate breakdown of the impulse generator by means of some triggering circuit. This method has the advantage that the impulse generator can be triggered off at will at any required instant.

The electrical transients recorded in high-voltage engineering are invariably of extremely short duration (usually of the order of a few microseconds) and some care must be taken to ensure synchronization of the waveform to be recorded with the time-base of the oscillograph. Since breakdown of all the gaps of an impulse generator follows very quickly when breakdown in the first stage occurs, it is necessary only to arrange



1 *Some spark-gaps used in the tripping of impulse generators*

for synchronization with the first-stage spark-gap. The tripping and synchronization procedure which is extensively used at the present time, therefore, is to remove the two-electrode spark-gap from the first stage of the impulse generator and to replace it with a multi-electrode spark-gap. A voltage pulse from the oscillograph is then used to trigger off a pulse generator having an output of several kilovolts, which in turn gives rise to a disturbance in the existing conditions of the spark-gap and causes breakdown. Several types of multi-electrode spark-gap are in use for this purpose, each of which can be made to break down at voltages less than its direct breakdown voltage on the application of a trigger pulse.

Several types of triggered spark-gap used in impulse-

generator tripping have been investigated by the author. Certain defects in the operating characteristics of these gaps have been found, and new gaps have been developed which give results superior to those of the more commonly used form of spark-gap.

A well-known tripping system employing a three-ball gap is shown in Fig. 1(*a*). The two gap lengths d_1 and d_2 are equal, and the central tripping sphere is maintained at a potential equal to half the charging voltage before the tripping pulse is applied. A tripping pulse of either polarity may be used and good operating characteristics are obtained. The impulse voltage is produced at the point marked 'output'.

Fig. 1(*b*) shows a circuit tripped by a system working on a different principle. A hole is drilled in the centre of the sparking surface of a hemispherical electrode E_1 and a rod electrode E_2 is arranged as shown to form an annular gap d_2 in the sparking surface. The main gap d_1 can then be made to break down at voltages considerably less than its direct breakdown voltage by the application of a voltage pulse of a few kilovolts to the central trigger electrode.

The two systems described above can be combined into the arrangement illustrated in Fig. 1(*c*). This method of tripping has been developed recently and will operate very successfully over a wide range of voltages while requiring a triggering pulse of only 5 or 6 kV with charging voltages of the order of 200 kV.

The tripping system given in Fig. 1(*d*) is of interest since it is the method by which it is proposed to trip the million-volt single-stage impulse generator now being installed in the Electrical Engineering Department of Manchester University. The main gap d_1 is set to a length just too great to allow breakdown due to the charging voltage alone. Breakdown in this gap is then initiated by applying a voltage pulse (of the same polarity as the charging voltage) to the point A. The potential at B thus rises by the same amount and the direct breakdown voltage of d_1 is exceeded. Breakdown occurs and an impulse voltage is produced, equal in magnitude to the sum of the charging and tripping voltages and of the same polarity. 621.319.5 : 621.316.5.064

An Electrostatic Analyser

A short review of a Measurement and Control Section paper (No. 1840) entitled 'An Electrostatic Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale', by S. E. Hunt, Ph.D., D. P. R. Petrie, M.Sc., K. Firth, B.Sc., and A. J. Trott. The paper was published individually in June, 1955, and it is republished this month in Part B of the Proceedings.

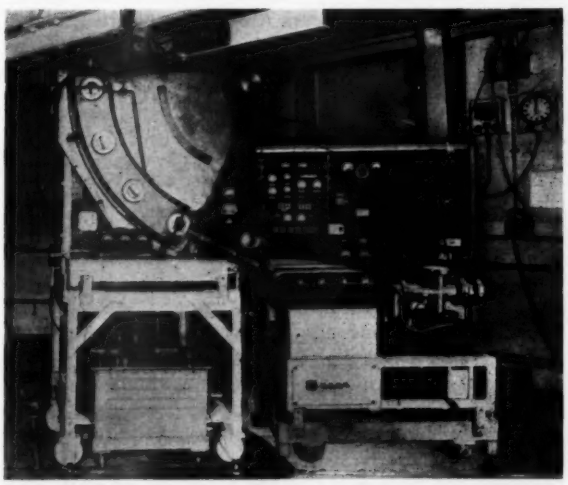
THE ENERGY OF THE PROTON BEAM FROM A PRESSURIZED electrostatic generator was measured by deflecting it along an arc of known radius between electrodes of accurately measured dimensions and configuration.

The angle of deflection [$\pi/(2\sqrt{2})$ radians] was such as to focus a broad incident beam on to a fine exit slit, and thus an energy resolution of 1 200 was obtained with only a slight loss of beam current. The voltages applied

1 *Analyser deflector electrodes mounted on base-plates*

to the electrodes were stabilized to a few parts in 10 000, and were measured by comparing them with the voltage of thermostatically controlled standard cells using accurate potential dividers and potentiometers. The beam energy was measured absolutely to an accuracy of about 6 parts in 10 000.

Beams of energy up to 3·25 MeV have been passed through the electrostatic analyser, and these were used to irradiate thin targets of fluorine and beryllium evaporated on to copper backings. The γ-ray yield from the targets was observed as a function of beam energy, and the energies for which resonant peaks occur was measured. These resonances correspond to energy levels in the compound nuclei formed by proton capture



2 *Analyser and magnet assembly*

by the target nuclei, and apart from their interest to nuclear physicists provide valuable calibration points in the high-voltage scale.

A strong resonance in the $F^{19}(p\alpha\gamma)O^{16}$ reaction was measured at 874·5 ± 0·9 keV. This is to be compared

with a value of $873{\cdot}5 \pm 0{\cdot}9$ keV obtained by Herb, Snowden and Sala, who also used an absolute electrostatic analyser.

Resonant peaks in the $Be^9(p\gamma)B^{10}$ and $Be^9(p\alpha\gamma)Li^6$ reactions were observed at $2{\cdot}567 \pm 0{\cdot}003$ MeV, $1{\cdot}0837 \pm 0{\cdot}0007$ MeV and $989{\cdot}5 \pm 1{\cdot}4$ keV. These had not previously been determined absolutely.

537.534 : 621.317.7.082.72

Nuclear Power

A short review of a Graduates and Students Section paper with the above title by J. K. Wood, M.Sc., Graduate. The paper was awarded a Students' Premium by the Council, and a long abstract of it was published in March, 1956, in the Students' Quarterly Journal.

COAL MAY BECOME AN UNECONOMIC FUEL IN ABOUT 200 years, and British sources of it will be uneconomic before this. Oil and natural gas will be seriously depleted in a far shorter time. Potential hydro-electric sources are often widely separated from the centres of demand; some would be difficult to tap and many would be uneconomic by present standards. It would be impossible to increase the generating capacity beyond a certain maximum, which is estimated to be about 75% of the present power demand. Nuclear fuels, uranium and thorium, exist widely in nature, and on the basis of an expenditure of £50 per pound of pure metal extracted enough fuel exists to supply the entire present-day energy requirements for 1 500 years. Coal and oil are valuable raw materials for the chemical industry, and it is apparent, therefore, that energy sources alternative to them must be fully exploited in the near future.

The Release of Nuclear Energy

Natural uranium contains approximately 0·7% of uranium 235, and when the nuclei of uranium 235 atoms undergo fission, high-energy neutrons are released. In order to increase their chance of causing further fission, the neutrons must be slowed down to very low energy levels. During this slowing-down process they may be absorbed by the uranium 238 present, and in order to minimize this a material called a *moderator* is included which will slow down the neutrons without absorbing them. Uranium 238 that has absorbed a neutron eventually becomes plutonium, which is itself a useful nuclear fuel. If a reactor is built using a large proportion of uranium 235, absorption is not a serious set-back, and no moderator is needed. Such a reactor is much smaller than a natural uranium reactor, and if it is surrounded by a blanket of uranium 238 more plutonium is produced than uranium 235 consumed. A reactor of this type is known as a *breeder* reactor.

Thermal Reactors

It has been shown that a reactor consisting of either pure natural uranium, or a homogeneous mixture of moderator and natural uranium, will not maintain a chain reaction. The uranium must be dispersed in the moderator in a system of discrete lumps, so that many of the neutrons lose their energy where no uranium 238 is present. If the reactor is surrounded by a layer of moderator, some of the neutrons which would have been lost re-enter the reactor after several collisions in this layer. This increases the efficiency, reduces the critical size and mass of the reactor and spreads the region of high heat dissipation. Suitable moderators are graphite and heavy water. If heavy water is used in such a reactor, boiling must be prevented, and therefore, since high pressures are impracticable in a reactor of large size, the outlet temperature must be low.

Structural materials suitable for use in the interior of a reactor are beryllium, magnesium, aluminium and zirconium. The uranium fuel elements are sealed in aluminium cans to prevent the escape of radioactive material and to prevent chemical reactions between the uranium and the coolant.

A reactor is built larger than the critical size and equipped with control rods made from material of high neutron-absorption coefficient; these are withdrawn when it is desired to start the reaction.

Chemical Processes

Economically workable deposits of uranium are found, among other places, in the Belgian Congo, Canada and Australia. The ore is concentrated at the source and transported to the extraction plant. Chemical processing of the spent fuel removes the plutonium and uranium and reduces the fission products to safe forms. All material which is used inside the reactor has to be extremely pure as traces of certain elements can absorb neutrons and seriously impede the reaction.

Radiation Hazards

In the event of an accident to a reactor, the area within a radius of half a mile becomes unsafe, and crops and dairy produce up to ten miles down wind can be affected. Plant is best kept in thinly populated areas with an exclusion area of several hundred yards radius round the reactor. Experimental reactors and chemical plant must be screened so that the radiation level is safe to workers nearby. Operating plant may have less screening as it will not require continuous supervision. Radiation detectors must be used liberally throughout the plant and by workers themselves to ensure that the radiation level does not exceed the safe maximum.

Some Economic Considerations

The capital outlay for a nuclear power station is high and running costs are low. Consequently nuclear power stations will be used to supply base loads. Reactors of a given type do not differ greatly in size, so that the higher the rated heat output the lower will be the capital cost per unit of power. As more power stations are built, more plutonium will be produced, and its value will fall.

The cost of generating electricity by this method is about 0·6d./kWh at the generating-station terminals. A ten-year plan for nuclear power stations has been launched, providing for a generating capacity of 1 500–2 000 MW by 1965. This programme will cost about £300 000 000.

Future Developments

If the fuel cycle and chemical process could be entirely remotely controlled, lower purity would be acceptable and great savings could be made in chemical plant. One ton of uranium occupies a volume of about 12 gallons. If the chemical processes could be limited to volumes of this order then further savings could be achieved. Highly-rated fast reactors, charged with greatly enriched uranium or plutonium and using liquid metal coolants, may be used as mobile power units. Liquid-cooled reactors should be practicable for commercial power generators in about ten years. To obtain increased efficiency from water-cooled reactors, externally fired superheaters may be used in the steam cycle. Any method of generation which by-passes the need for a steam cycle will greatly increase the fuel utilization efficiency.

For the more distant future the advent of controlled thermo-nuclear reactions would ensure adequate power supplies for any needs. 620.93

SYNOPSES OF PAPERS

The following are synopses of papers published in the *Proceedings* without first being read at an Institution meeting which have not been described elsewhere in the *Journal.*

Oscillator Noise

A synopsis of a Radio and Telecommunication Section paper (No. 1968) entitled 'A Comparison of the Noise, and Random Frequency and Amplitude Fluctuations in Different Types of Oscillator', by R. L. Beurle, B.Sc.(Eng.), Associate Member. The paper is published this month in Part B of the Proceedings.

NO OSCILLATOR GIVES A PURE SINE-WAVE OUTPUT. THERE is always some random noise present in the oscillator circuit, if only that due to thermal agitation. Because of this, noise will appear in the output even if steps are taken to stabilize the output amplitude. Also, the output power is spread over a finite frequency band, and not concentrated at a single frequency.

The nature of the random fluctuation in the output is dependent on the form of feedback employed and the method by which the output amplitude is controlled. The frequency band over which the output power is distributed depends, however, on the relative magnitudes of signal and noise in the circuit rather than on the particular circuit employed. The conclusion is that an oscillator should be operated at as high a level as possible consistent with stability and constancy of the circuit components. 621.373 : 621.3.018

Cable Impedance

A synopsis of a Radio and Telecommunication Section paper (No. 1891) entitled 'The Choice of Impedance for Coaxial Radio-Frequency Cables', by W. T. Blackband, M.Sc., Associate Member. The paper was published in November, 1955, in Part B of the Proceedings.

THE CHOICE OF CHARACTERISTIC IMPEDANCE OF A COAXIAL cable is discussed. Among the cable properties considered are attenuation per unit length, voltage rating and power ratings based upon thermal and voltage limitations. A method is given for determining the optimum proportioning to satisfy a specification of two or more cable properties. It is shown that the criterion of cable diameter leads to conclusions little different from those based upon the criteria of dielectric or conductor cross-section. The best choice of impedance is 75 ohms for low-loss air-spaced cables, and 50 ohms for general-purpose thermoplastic cables. 621.315.212.029.5 : 621.3.011.21

Echo Distortion of Multiplex Signals

A synopsis of a Radio and Telecommunication Section paper (No. 2006) entitled 'An Extended Analysis of Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex', by R. G. Medhurst, B.Sc., and G. F. Small, B.Sc.(Eng.), Graduate. The paper is published this month in Part B of the Proceedings.

WHEN A FREQUENCY-DIVISION-MULTIPLEX TELEPHONY signal is subjected to some non-linear process, intermodulation distortion is generated, being usually audible as an unintelligible noise. In f.m. systems an important source of such non-linear distortion is to be found in small echoes of the main r.f. signal. Albersheim and Schafer have investigated theoretically and experimentally the distortion due to a single echo, but the analysis applied only to limited ranges of the available parameters and the agreement with experiment was not always good. It now appears that Albersheim and Schafer's results can be extended to enable prediction of distortion levels for most cases of practical interest. Most of the discrepancy between theory and the measurements of Albersheim and Schafer can also be accounted for, the formulae being in good agreement with measurements carried out by the present authors. 621.376.3 : 621.3.018.78

OBITUARY

RICHARD HILL ASPERNE DEANE

Richard Hill Asperne Deane, who died on the 28th October, 1955, was born on the 15th May, 1886. He received his practical training at Rawlings Bros. from 1903 to 1907 and his electrical engineering education by part-time study at the Regent Street Polytechnic from 1904 to 1908.

In 1907 Mr. Deane joined the St. James's and Pall Mall Electric Light Co. as Assistant Engineer, and was later appointed Charge Engineer, Resident Engineer and finally Station Superintendent of the St. James's and Mayfair Districts after the Central London Electricity Co. was formed in 1936. For a period of his early days with the St. James's and Pall Mall Electric Light Co. he was loaned to the Central Electric Co. and gained experience of generation at Grove Road power station. He also had experience of the early steam generating stations at Carnaby Street and Mason's Yard, which at that time were equipped with Willans engines. He therefore saw many changes in systems of supply, including the change-over from steam generation to bulk-supply d.c. distribution, and the establishment of the standard a.c. systems which exist to-day.

One of his principal hobbies was motoring, of which he was an ardent follower for 46 years, and he claimed the distinction of having been Chairman of the Graduates Founding Committee of the Institution of Automobile Engineers. His knowledge of cars and internal-combustion engines was legendary.

Richard Deane was of a modest disposition with a quiet, dry sense of humour. A conscientious engineer who gained the respect of his many colleagues during the years he served in the supply industry, he will be sorely missed by those who knew him.

He joined The Institution as a Student in 1909, and was elected an Associate Member in 1912 and a Member in 1948. He was also a member of The Institution of Mechanical Engineers. R. G. M.

LAWRENCE FRANCIS ALEXANDER FOGARTY

Lawrence Francis Alexander Fogarty, who died on the 9th July, 1955, was born on the 1st July, 1882. He was educated at St. Michael's Grammar School, London, and received practical experience from 1896 to 1900 as an apprentice to the Success Manufacturing Co., London, makers of cycle and motor-cycle components and ignition equipment. From 1900 to 1918 he was employed as a switchboard assistant with the Westminster Electric Supply Co., Assistant Electrician with the Great Western Railway Co., and as Technical Assistant in the firm of Isenthal of London, where he was engaged on the design and manufacture of electromedical and physical apparatus, surge-protection devices, control gear and radio equipment. While he was with this firm he rose to the position of Works Manager and eventually, after the firm was incorporated, became a Director. During this period, from 1900 to 1912, he studied general and electrical engineering in the evenings at the Regent Street, Northampton and Willesden Polytechnics.

In 1918, Mr. Fogarty was appointed Managing Director of a new business, which later became the Zenith Electric Co., and he remained as head of this company until his death.

Mr. Fogarty's public activities were many and varied. He served in the Metropolitan Special Constabulary, attaining the rank of Chief Inspector, and was a member of the Ruislip and Northwood Urban District Council for seventeen years, including three years as Chairman. He became a Justice of the Peace in 1938 and was appointed a permanent J.P. for the County of Middlesex in 1941. He served as Vice-Chairman of the Uxbridge Petty Sessional Division from 1951. During the Second World War he was Chairman of the local Civil Defence Committee.

He was a member of various B.S.I. technical committees, and together with Mr. R. H. Klein and Mr. L. McMichael he founded the Wireless Society of London, which later became the Radio Society of Great Britain.

His unfailing courtesy and sound judgment endeared him to his many friends and business associates by whom he will be greatly missed.

Mr. Fogarty joined The Institution as an Associate Member in 1914 and was elected a Member in 1926. He was also a Fellow of the Royal Society of Arts. G. R.

JOSEPH ALEXANDER PANTON

Joseph Alexander Panton, who died on the 18th March, 1955, was born on the 1st March, 1874. After a public-school education he was apprenticed to the firm of Paterson and Cooper of Glasgow in 1893 where he was engaged in the installation of electric lighting and power. After three years he was promoted to the rank of foreman and gained experience in armature building and general dynamo construction. While in Glasgow he attended evening classes at the University. In 1898 he was appointed Electrical Engineer to the Allan Line Steamship Co. of Liverpool, in which capacity he was responsible for the electric lighting, power and wireless telegraphy of their fleet of steamers. At Liverpool in his spare time he applied himself to experimental work and research under Sir Oliver Lodge.

He joined the Liverpool Overhead Railway Co. in 1903 as Superintendent of railway and tramway rolling stock and later became General Assistant for the entire equipment. From 1908 to 1911 he served as Assistant Engineer, during which period he patented the geared signal arm and the refill steel-backed brake blocks for railways and tramways. Mr. Paton subsequently joined the National Rail and Tramway Appliance Co. as General Manager and then became Managing Director, but in 1914 he started in practice as a Consulting Engineer. For 20 years he was fully employed as an expert witness on machinery accidents, and re-entered this vocation after 1945.

Mr. Paton was a member of the Tramway and Light Railway Association, and served on the Special Committee of Enquiry on Rail Corrugation set up by the Municipal Tramway Association.

He joined The Institution as an Associate Member in 1904 and was elected a Member in 1911. He was the author of a paper entitled 'Rail Corrugation' which was published in the *Journal* in 1907. He was also an Associate Member of The Institution of Mechanical Engineers. H. M. R.

MONOGRAPHS AND PAPERS
published individually this month

Monograph, Individual Paper and Reprint Service

Synopses of monographs and papers published individually before the next issue of the Journal are given below, and, unless otherwise stated, their dates of publication are this month. Reprints of all papers are available about two months after publication in the Proceedings. The prices shown below are post free. When ordering please quote serial number of paper or monograph. Books of 8 vouchers may be obtained from the Secretary, price 10s. each.

There are special arrangements for the papers to be read at the Conference on Digital-Computer Techniques. See the announcement on page 204.

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MONOGRAPHS

The Determination of the True Side-Lobe Level of Long Broadside Arrays from Radiation-Pattern Measurements made in the Fresnel Region

MONOGRAPH No. 169 R

R. H. T. BATES, B.Sc.(Eng.), and J. ELLIOTT, M.Sc.

The radiation pattern in the Fresnel region is expressed as a function of the far-field polar diagram. By this it is shown how the true side-lobe level may be inferred from amplitude radiation-pattern measurements made in the Fresnel region. This results in considerable shortening of the range at which polar-diagram measurements may be made.

Possible Errors of a Particular Wide-Aperture Direction-Finder

MONOGRAPH No. 170 R

W. C. BAIN, M.A., B.Sc., Ph.D.

A study is made of the extent to which the high-frequency cyclical direction-finder devised by Earp and Godfrey is subject to three common types of error. First is presented the result of theoretical computations on the errors given by a practical fixed-aerial system in wave-interference conditions. The variance of these errors, as the phase difference between the incident rays is varied, is shown to be the same as that given by the ideal rotating-aerial version of this direction-finder; it is appreciably smaller than that of an Adcock direction-finder for a system aperture of 4λ, and, in general, much smaller for an aperture of 10λ. Secondly, errors due to aerial interaction are considered for a system of 24 unipoles, 9 m high and 1·1 m in diameter, placed on a circle of 100 m diameter. It is concluded that the errors in indicated bearing are likely to be negligible provided that the aerials not in use at any instant are terminated by a resistor equal to their nominal characteristic impedance.

An Audio-Frequency Dynamometer Wattmeter

MONOGRAPH No. 171 M

A. H. M. ARNOLD, Ph.D., D.Eng., and J. J. HILL, B.Sc.

Negative-feedback amplifiers are used to supply the currents to the coils of a nickel–iron-cored dynamometer and by this means indications proportional to current, voltage or power in an external circuit may be obtained at any frequency between 50 c/s and 20 kc/s. The signal voltage required at the amplifier input terminals for full-scale instrument deflection is 2 volts. A voltage divider having a resistance of 1000 ohms/volt and time-constant ratios of less than $0{\cdot}02\,\mu$H/ohm is used to give eight voltage ranges up to 500 volts. The current ranges are obtained by using four terminal resistance standards of different values and having time-constants of less than $0{\cdot}02\,\mu$H/ohm.

PAPERS

Physical Properties and Impulse Strength of Paper

PAPER No. 2024 S; PART A

H. C. HALL, M.Sc., and E. KELK, M.Sc., A.Inst.P.

The paper will be published on April 16th.

It is shown that the impulse strength of oil-impregnated paper, measured on single sheets, is related to the impulse strength of a lapped dielectric using the same paper.

Attempts are made to relate the impulse strength to physical characteristics of the paper. General relationships involving apparent density and air impermeability are indicated, but it is shown that, in addition, account needs to be taken of some measurement of uniformity. Means for obtaining such a measurement on small areas of paper are described.

The Impulse Strength of Lapped Impregnated Paper Dielectric

PAPER No. 2025 S; PART A

H. C. HALL, M.Sc., and D. J. SKIPPER, B.Sc.(Eng.)

The paper will be published on April 16th.

An investigation of the impulse strength of lapped impregnated paper dielectric has been made using model cables. The subjects studied include the effects of variation in the physical properties of the paper and the impregnant, the effects of variations in construction of the dielectric, and the effects of temperature and pressure. In addition, the response to different test procedures, such as polarity, polarity reversal and repeated stressing, has been examined.

The breakdown process, with impulse voltages, is discussed in the light of the results obtained. Both components—the paper and the oil—are shown to be effective in determining the impulse strength of the composite dielectric.

Breakdown under Impulse Voltages of Solid and Liquid Dielectrics in Combination

PAPER NO. 2050 S; PART A

W. G. STANDRING, M.A., and R. C. HUGHES, B.Sc.

The paper will be published on April 16th.

The progress of an investigation of the breakdown of solid and liquid dielectrics in combination is described, and generalizations are made on the effects of electrode shape, of impulse duration and of polarity on the puncture voltage of alternate layers of solid and liquid, and on the flashover voltage of a solid and liquid interface under various conditions of stress.

Temperature Rises in Electrical Machines as related to the Properties of Thermal Networks

PAPER NO. 2026 U; PART A

J. J. BATES, Ph.D., and PROFESSOR A. TUSTIN, M.Sc.

The paper will be published on April 9th.

The conditions are reviewed under which an electrical machine may usefully be regarded, for the purpose of relating temperature rises to losses, as a thermal network of lumped conductances and capacitances, having an electrical analogue.

Although the thermal resistivities are distributed it is shown that lumped-resistance networks may be found that reproduce the relationships between the inputs of heat to the parts and the mean temperature rises over the volumes of the parts. Sources of non-linearity are considered, and in many cases a linear model is adequate.

A novel timing device, a novel slip-ring contact for use with temperature detectors on rotating parts, and some details of resistance-type temperature detectors are described.

Temperature Rises in Electrical Machines on Variable Load and with Variable Speed

PAPER NO. 2031 U: PART A

PROFESSOR A. TUSTIN, M.Sc., and J. J. BATES, Ph.D.

The paper will be published on April 9th.

In selecting an electrical machine it is required to estimate how hot the windings will become when the most onerous duty anticipated is performed. This has been difficult when the duty involves varying loads and speeds. Relationships are given by which such estimates may be based on the results of temperature measurements on a machine of the type in question resulting from sustained operation of the on-off type. The data required to specify the capabilities of a machine can be given by two curves, and so may be included on the data-sheet for a machine of given type. No measurement or specification of the energy losses as such is required, the method being essentially a comparison between the set or combination of various operating conditions that constitute the duty, weighted according to the time each condition holds, with measurements for representative operating conditions on the test-bed.

Performance and Heating Curves for Motors on Short-Run Duties

PAPER NO. 2036 U; PART A

PROFESSOR A. TUSTIN, M.Sc., D. F. NETTELL, B.Sc., and R. SOLT, B.Sc.(Eng.)

The paper will be published on April 9th.

It is shown how curves may be prepared that facilitate the design or selection of motors for services with short runs such as the operation of cranes or urban transport. The values of such quantities when operating on a statistically specified schedule may be estimated from such curves, with little further calculation, for various combinations of motor windings, gear ratios, accelerating currents, and the other quantities open to choice.

The procedure is based on the definition of the conditions under which the characteristic curves of the motor and the speed-time curves in operation are of similar shape. One condition for this is that the magnetization curves of the motors should themselves be similar. For classes of motor and operation satisfying these conditions for similarity various required quantities may be given by single curves with scale factors.

The principles are illustrated by the development of curves giving run-times, current-consumption, motor-heating coefficients and other quantities that result from the operation of series-wound motors having magnetization curves of the shape found to be characteristic for modern mill-type motors.

Nuclear-Reactor-Control Ionization Chambers*

PAPER NO. 2029 M; PART B

W. ABSON, B.Sc., and F. WADE

The paper describes the design and electrical characteristics of a neutron-sensitive d.c. ionization chamber suitable for a wide range of applications in nuclear-reactor-control instrumentation systems. Thermal-neutron sensitivities of 10^{-15}–10^{-14} amp/n/cm^2/sec can be obtained using boron trifluoride filling or boron-coated electrodes with hydrogen filling. The corresponding γ-radiation sensitivities are of the order of 10^{-12}–10^{-11} amp/r/h. Virtually complete collection of the ionization current is possible, up to neutron-flux levels of 10^{11}n/cm^2/sec, with a polarizing voltage of a few hundred volts. The residual current due to neutron-induced activities in the chamber falls to less than 10^{-6} times the full-power neutron current some 20 min after shut-down.

Some Design Aspects of Nuclear-Reactor Control Mechanisms*

PAPER NO. 2046 M; PART B

G. E. LOCKETT

The paper outlines some of the practical design problems associated with the engineering of control mechanisms in nuclear reactors. Safety is emphasized in all the design aims, and examples are given of some of the systems in use at Harwell. The scope of the paper is limited to control mechanisms for low and moderate-power experimental reactors, although some of the problems which will be met in future power-producing reactors are mentioned.

The Control and Instrumentation of a Nuclear Reactor*

PAPER NO. 2058 M; PART B

A. B. GILLESPIE, B.Sc.

The control and instrumentation of nuclear reactors is a rapidly developing subject which is becoming of increasing importance to a growing body of instrument engineers. Many of the problems of instrumental design are common to other industrial plants, and follow conventional lines. Some, however, are more specialized, and arise principally from the radioactive nature of the plant and its unusual dynamic behaviour. The paper presents a survey of the overall instru-

* British Nuclear Energy Conference papers.

mentation of a typical research reactor. Emphasis is placed on the lesser-known problems of measurement and control; to assist in their understanding a brief account is given of the mode of operation of a nuclear reactor, and a short section on reactor kinetics is also included. The types of instrument in present-day use are described, and indications are given of their shortcomings. New developments are briefly reviewed. The paper concludes with a section on reactor safety.

The Control of Nuclear Reactors*

PAPER No. 2068 M; PART B

R. J. COX, B.Sc., and J. WALKER, M.A.

The physical principles of nuclear reactors which affect the design of their control and instrumentation are described. Data are presented for the kinetic behaviour of the neutron flux for reactivity changes in a variety of reactor types. The nuclear reactions inherently produce various nuclides, and the effects of these on reactor control and operation are discussed. These nuclides include the delayed neutron emitters which cause a slowing of the reactor kinetic response, beta and gamma emitters which continue to produce heat for a long time after the neutron reaction producing them has been shut down, and the fission-product poisons. Reasons are given for the system of neutron-flux instruments normally used, and details are given of the principles of design of the various types of instrument.

A Point-Contact Transistor Scaling Circuit with 0·4 microsec Resolution

PAPER No. 2064 R; PART B

G. B. B. CHAPLIN, M.Sc., Ph.D.

There is a wide choice of scaling devices which will operate at maximum counting rates up to several hundred thousand per second, but for higher counting rates the choice is limited almost entirely to either special thermionic scaling devices or circuits using thermionic valves. Such circuits tend to be rather complex and have a relatively high power consumption.

The paper describes some scaling circuits using transistors which will resolve 0·4 microsec and hence count at a maximum rate of $2{\cdot}5 \times 10^6$ per second. The transistors are the normal point-contact type, and the circuits are simple, have wide tolerances and are economical in power consumption.

Features which contribute to the short resolving time are the prevention of bottoming of collector potential and the absence of capacitors. A typical scale-of-ten circuit uses 7 transistors, 7 pulse transformers and 14 crystal diodes.

The Crystal Palace Television Transmitting Station

PAPER No. 2069 R; PART B

F. C. McLEAN, C.B.E., B.Sc., A. N. THOMAS and R. A. ROWDEN, B.Sc.(Eng.)

The paper gives an account of the siting, planning, and design of the Crystal Palace station. The steps taken to attain a high standard of reliability, and the considerations that determined the selection of the Crystal Palace site and of effective radiated power and aerial gain are stated. The requirements with which the installation had to conform are given, and the building, plant, and equipment described. The design and construction of the aerial system are discussed, with information about its performance.

* British Nuclear Energy Conference paper.

The Broadcasting House–Crystal Palace Television Link

PAPER No. 2072 R; PART B

A. R. A. RENDALL, Ph.D., B.Sc., and S. H. PADEL, B.Sc.

The initial requirement for the Broadcasting House–Crystal Palace television link is for one channel in each direction, but it is likely that a second channel will be needed later. The transmission of two programmes over a single tube will make the 0·975-inch coaxial cable that is used economic over this distance of 9 miles, and such cable permits transmission between terminals without intermediate equipment. To meet the need of good performance with simple low-cost equipment, a double-sideband system with amplitude modulation has been developed. To allow for later development as, for example, a wider-band channel for colour, the carrier frequency of the monochrome channel has been placed at 15 Mc/s.

In the transmitting terminal the video signal is translated into the band for transmission over the cable and in the receiving terminal the incoming signal is corrected for the loss, attenuation and delay distortions which occur in transmission, and the video signal is recovered. The performance of the link is given in terms of the measured amplitude and differential delay characteristics, transient response, linearity and signal-to-noise ratio.

Band I Television Transmitter Design with particular reference to the Transmitters at Crystal Palace

PAPER No. 2075 R; PART B

V. J. COOPER, B.Sc.(Eng.), and W. J. MORCOM, B.Sc.(Eng.)

The paper describes television transmitting equipment designed to operate in two parallel chains to ensure reliability. The vision transmitters are designed to work with considerable distortion and noise in the input signal, and the noise-rejection and clamp circuits developed for this purpose are discussed. The use of tetrodes in the output stage of the vision transmitter enables receiver-type valves to be used throughout the modulator, and permits the advantage of high-level modulation to be exploited. The methods of phasing of both radio and vision frequencies are described. The paper discusses the implications of colour television on design and states the means adopted in these transmitters to assure faithful colour transmission.

A Junction-Transistor Scaling Circuit with 2 microsec Resolution

PAPER No. 2076 R; PART B

G. B. B. CHAPLIN, M.Sc., Ph.D., and A. R. OWENS, M.Sc.

When junction transistors are used in conventional scaling circuits the maximum speed of operation is limited by the associated circuit, mainly owing to the use of capacitors, which require time to charge and discharge. The limiting speed of a transistor itself which is dependent upon the turn-on and turn-off times of current, is generally several times higher than this but cannot be used to advantage because of the associated circuit.

The basic binary scaling circuit described in the paper overcomes this by dispensing with capacitors, a differentiating transformer being used instead for coupling. In this way the speed of the circuit is dependent only upon transistor characteristics. With currently available low-frequency junction transistors the circuit is capable of resolving 2 microsec.

TECHNICAL PUBLICATIONS

BRITISH STANDARDS AND CODES OF PRACTICE

The Secretary has been asked to draw attention to the following publications, copies of which can be obtained from the British Standards Institution, 2 Park Street, London, W.1. The prices given for each Standard are post free.

GLOSSARY OF TERMS RELATING TO AUTOMATIC DIGITAL COMPUTERS (B.S. 2641: 1955). 3s.

The development of high-speed digital computers has produced a need for the standardization of the terms used in this technique. In the early stages it was thought that methods were changing so rapidly that attempts to draft a glossary would be inadvisable; in recent years, however, techniques have reached a more stable state. The Standard contains about one hundred entries, covering fundamental terms, coding systems, storage techniques (mainly electronic) and programming and routines. For completeness a few definitions relating to number representation and number scales are included.

MAINTAINED LIGHTING IN CINEMAS (C.P. 1007: 1955). 5s.

The Cinematograph (Safety) Regulations, 1955, require that there shall be available on the premises two independent supplies for lighting, namely a supply for the general lighting and a supply for the safety lighting, the latter by itself providing illumination in the public parts of the building sufficient to enable members of the audience to see their way out.

A Code of Practice relating to 'Maintained Lighting in Cinemas' has been prepared by a committee widely representative of the licensing authorities, cinema exhibitors, architects and professional organizations concerned with illumination; and during the course of its work many measurements were made in cinemas of varying age and size.

The factors which influence the effectiveness of cinema lighting, particularly the subdued lighting in the auditorium, are so numerous and varied that it is impracticable to prescribe a precise quantitative value for a minimum level of illumination. The purpose of this Code is to enable these factors to be assessed when new cinema buildings are being designed, and when lighting installations in existing cinemas are being reviewed. It gives guidance on the general lighting of cinemas, and indicates how the effectiveness of the lighting is influenced by such features as the architectural proportions and planning of the building, the layout of the seating, the location of the exits, the decorations and furnishings, and the brightness of the screen or stage.

The recommendations are primarily intended for new cinemas but most of the considerations apply equally to the modification of existing installations or to the adaptation of premises hitherto used for other purposes.

THE CANADIAN STANDARDS ASSOCIATION APPROVALS SYSTEM. INFORMATION FOR U.K. MANUFACTURERS EXPORTING ELECTRICALLY-OPERATED EQUIPMENT TO CANADA (PD1533: 1955). 5s.

Virtually all the £9 million worth of British electrical equipment sold to Canada each year (with the exception of some heavy plant for power stations) now receives, before it leaves this country, a seal of approval from the British Standards Institution, acting as agent for the Canadian Standards Association. This means that such equipment goes straight into service without the risk of being returned to Britain for costly alterations. This system of approval-in-advance is now successfully used by some 400 British firms making products from electrically operated machine tools to electric kettles. Very many thousands of separate products have already been approved.

To further strengthen the approvals service the British Standards Institution has now published a completely new and greatly enlarged edition of its booklet PD1533. This booklet first appeared in 1952 and has been reprinted a number of times to keep its contents up to date.

E.R.A. REPORTS

The Secretary has been asked to draw attention to the undermentioned E.R.A. Reports. Copies can be obtained from the British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. The price of each report is given, and unless otherwise stated, the cost of postage on a report is 3d.

E/T59. 'TRENDS IN EARLY INSULATING OIL SPECIFICATIONS'. BY E. A. EVANS. 4s. 6D.

The report comprises a review of some of the early work done by the E.R.A. Insulating Oils Committee since it was set up in 1921.

Q/T124. 'STRAY LOSSES IN TRANSFORMER CORES. CRITICAL RÉSUMÉ'. 12s. (POSTAGE 4D.).

This report briefly reviews the calculation of iron losses in transformer cores. Digests are given of articles treating losses in joints, corners, interlamination insulation, and subsidiary parts such as core bolts and clamps, as well as losses due to strains in the iron. The calculation of apparent loss in a given shape of core is considered and a bibliography is appended.

Q/T125. 'STRESSES IN HIGH-VOLTAGE CONDENSER-BUSHINGS'. BY S. SILBERMANN. 12s.

The stress distribution in insulators and in high-voltage bushings, especially of the condenser type, has been investigated by many authors, and theoretical solutions for different kinds of electrodes have been obtained. However, no actual practical values of the stresses involved can be found in the technical literature. Experience shows that in most of the breakdowns which still occur the failures are mainly in the vicinity of the edges of the last conducting layer near the flange, which reveals that the stresses in this part of the bushings must be exceedingly high.

The report deals with the problem of stresses in high-voltage condenser bushings from a practical point of view, gives actual figures of the stresses involved and shows how the excessive stresses can be reduced.

W/T25. 'THE APPLICATIONS OF ELECTRICITY TO CROP DRYING ON FARMS. A CRITICAL REVIEW'. BY P. FINN-KELCEY. 24s. (POSTAGE 1s.).

A comprehensive review which covers the drying of herbage crops as well as of grain and seeds. Methods of drying grass with and without heat are discussed, and the different types of apparatus are described. Barn hay-drying and drying methods for grain, seed and hops are also dealt with. A bibliography of 41 references is appended.

Z/T92. 'INVESTIGATION OF DETERIORATION OF MOULDED CARBON RESISTORS: FIRST REPORT'. BY H. F. CHURCH AND J. J. WALSH. 7s. 6D.

This report describes briefly the results obtained during the first twelve months of a research programme to investigate the deterioration of moulded carbon resistors. The programme may be divided into two parts; (*a*) a general study of the mechanism of conduction, and (*b*) life test investigations.

Z/T96. 'INVESTIGATION OF DETERIORATION OF MOULDED CARBON RESISTORS: SECOND REPORT'. BY J. J. WALSH AND H. F. CHURCH. 12s. 6D. (POSTAGE 4D.).

This report is a continuation and expansion of an earlier report, Ref. Z/T92. The investigation comprised (*a*) a general examination of resistors, including the measurement of temperature and voltage coefficient and the study of humidity effects and noise, and (*b*) life tests. The life tests show that long life is dependent upon thorough wax impregnation, and that the physical and chemical stability of the wax used is of great importance.

SOME RECENT BOOKS

FARRINGTON DANIELS and **JOHN A. DUFFIE** (*Editors*)
SOLAR ENERGY RESEARCH

THAMES AND HUDSON. 304 PP. 30S.

In the hope of reducing the high rate of exhaustion of the world's capital reserves of fossil fuels, an active search is being made for insufficiently exploited, 'income' sources of energy, and attention has been focused on the potentialities of solar radiation for this purpose. During the last few years much thought has been given to this subject, and research, in the United States and to a smaller degree in India, France, Russia, Israel, Australia and other countries, is beginning to show results in practical shape. Experimental equipment for water and space heating, cooking, water distillation and the production of very high temperatures for the melting of metals, has been successfully operated. Quite recently it has been announced that an efficiency of 11% has been achieved in the United States with a solar battery which converts the radiation directly into electrical energy by photo-chemical action. With the exception of geothermal, nuclear and tidal energy, all the sources at present used for power production are, or have been, supplied from the sun, which radiates to the outside of the earth's atmosphere an estimated energy of $1{\cdot}6 \times 10^{18}$ kWh annually. This total is many thousandfold greater than the world's present annual consumption of energy so that there is, indeed, plenty of scope for development if the technical and economic problems of its exploitation can be solved.

The appearance of 'Solar Energy Research' is timely, giving, as it does, a full and well-presented account of the proceedings at a conference on the subject at Madison, Wisconsin, in September, 1953. Largely as a result of this meeting the Association for Applied Solar Energy was formed, and this led, in turn, to the World Symposium and Conference on Applied Solar Energy held in Arizona in November, 1955. The papers at the Arizona Symposium amplified the information given in this book and indicated the large amount of research and development work which has taken place within the last two years and which the Madison conference inspired.

Starting with an assessment of the probable future energy demands and methods of power generation, in which it is estimated that 100 years hence some 15% of the total might be derived directly, or semi-directly, from the solar 'income', the book covers the characteristics of solar radiation, its use for various domestic and industrial heating purposes and for power production in different ways including photo-synthetic and photo-chemical utilization.

The introductory and concluding notes of Professor Daniels show the clear and forthright approach which characterizes his work on this subject, while Mr. Duffie gives, as an appendix, a useful survey of U.S. patents relating to the utilization of solar energy. The book also includes a valuable bibliography.

Although, until the summer of 1955, the sun has in recent years seemed reluctant to give more than fleeting glimpses of itself in the British Isles, there are good prospects of putting its radiation to use in extensive under-developed tropical areas.

S. GLASSTONE and **M. C. EDLUND**
THE ELEMENTS OF NUCLEAR REACTOR THEORY

MACMILLAN. 423 PP. 35S.

With the current interest in power and research reactors, a book such as this is greatly needed. It is based upon a course on nuclear reactor theory given at the Oak Ridge School of Reactor Technology for scientists and engineers who plan to enter the field of nuclear reactor science and engineering. The emphasis throughout the book is on the theoretical principles which form the basis of many reactor calculations. The book is confined to a discourse on 'thermal' reactors, that is reactors in which the majority of fissions are caused by neutrons having a kinetic energy equal to that of the atoms in the reactor.

The first few chapters deal with nuclear physics and are primarily concerned with neutrons, their properties and their interaction with matter. These chapters thus provide the basic nuclear information necessary for those who are new to the subject.

The succeeding chapters consider the diffusion and slowing down of neutrons; Fermi's continuous-loss-of-energy model is introduced and used to solve some problems. The theory of resonance escape probability is treated at some length. The theory of the critical condition, size and neutron balance in bare homogeneous reactors is then developed, together with the form of the neutron flux distributions. A chapter on the

homogeneous reactor with a reflector introduces the two-group-diffusion method for describing the slowing down of neutrons, a method which is extensively employed in reactor calculations. The heterogeneous reactor, in which the uranium is distributed in lumps throughout the core, is considered, and the formulae for calculating the resonance escape probability, thermal utilization and fast fission factor are derived.

The important topic of the time behaviour of bare reactors is thoroughly discussed in one chapter, the role of delayed neutrons in controlling a pile being well treated. This chapter is then followed by one on reactor control, in which the effects on the operation of the pile of fission-product poisoning, temperature, and control rods are considered.

The final three chapters, which are more mathematical, are devoted to the general theory of multiplying systems, perturbation theory and transport theory.

Problems are provided at the end of most chapters and these help the reader to overcome the feeling that, though a very sound mathematical treatment of reactors has been provided, the subject matter is somewhat divorced from the problem of designing reactors. Sufficient declassified data is given for reactors to be designed and their operating characteristics studied. A much larger selection of declassified material is now available and if some of this could be included the usefulness of the book would be greatly enhanced.

The book, because of its theoretical basis, is probably of more use to the graduate physicist who is interested in reactor theory, than to an engineer, unless the latter has a strong mathematical bias. However, it constitutes a reference book essential to anyone who is intimately concerned with reactor design and characteristics.

P. GRIVET and others.

OPTIQUE ÉLECTRONIQUE. VOL. 1. LENTILLES ÉLECTRONIQUE

FRANCE: BORDAS. 184 PP. £1 10S. 6D.

This treatise on electron lenses, the first of a series of three on electron optics, well fulfils the description 'Précis' which appears on the cover. It is a précis of much of the work which has been done on electron lenses and their applications, incorporating sufficient fundamental ideas and first principles to put the novice at his ease, but leading via a skeleton of easily digested mathematics to a selection from modern advances. There is an excellent chapter on the relation between visible and electron optics, and the differences in the natures of their respective aberrations. There is a clear and gentle introduction to the iconal method, which, as the authors point out, is too often feared as a 'mysterious art leading to curious calculations'.

The main reservation one has about this book is that the discussion in the chapters on electron lenses is largely based on old material. The extensive chapter on electrostatic lenses discusses mainly the results of French workers, its section on electron guns being rather inadequate and out of date. In the chapter on magnetic lenses, more recent (i.e. post-war) work on the properties of these lenses and the practical techniques of correcting certain of their aberrations is mentioned only in passing.

The book contains a few errors in presenting the work of other authors, e.g. concerning the accuracy of field plotting by resistance-networks, and Scherzer's correction system for spherical aberration (Fig. 69). The many misprints are, fortunately, not scientifically significant.

H. A. E. KEITZ

LIGHT CALCULATIONS AND MEASUREMENTS

EINDHOVEN: PHILIPS' TECHNICAL LIBRARY. 429 PP. £2 12S. 6D.

This book is essentially practical and explains in a simple manner the principles and applications found in textbooks on photometry. It should for this reason appeal to the student and be invaluable to the lighting engineer. Photometric concepts and methods of calculation are explained in a simple manner which will appeal especially to those not familiar with advanced mathematics and classical theories.

The subject is dealt with in two parts. The first seven chapters form Part 1, Light Calculations, which deal with solid angle, luminous intensity and flux, quantity of light, light distribution, illumination, luminance, non-point sources, reflection, absorption, transmission, optical systems and measuring units. A further eight chapters forming Part 2, Measurement of Light, cover visual and physical photometry and give details and simple descriptions of the techniques and apparatus employed when making various light measurements. In an appendix brief reference is made to the work of the International Commission on Illumination and the subjects which it covers. A strictly limited bibliography is included, and also some useful tables of data for lighting calculations and examples of light distribution of lighting fittings.

The author deals with the practical aspects of the subject in an interesting manner and the simple explanations in Part 1 are especially commendable. Throughout the book, however, and particularly in Part 2, the author gives the impression of being rather more familiar with American and Continental practice than with British. A few of the recent references tend to give the impression that the treatment is really up-to-date, but this is not borne out in the descriptions of instruments and techniques. Some of these have now been superseded and there appear to be omissions of more recent developments. This applies especially to improved standard lamps and photo-electric techniques which have been developed during the last ten years or so. In consequence the book presents a somewhat unbalanced view.

E. B. MOULLIN

ELECTROMAGNETIC PRINCIPLES OF THE DYNAMO

OXFORD: CLARENDON PRESS. 378 PP. £2 10S.

Professor Moullin's new book discusses the electrical machine in a manner which shows clearly how the theory of operation is derived from the fundamental laws of electromagnetism. Of the many other textbooks on this subject, the only one that is equally clear in this respect is the translation of Langlois-Berthelot's work.* It is obviously of great importance that the subject should be presented to the student in this way and these two books will be very valuable. To a great extent the aim is achieved of never making a statement without giving a reason for it—in fact for many results two or even more alternative explanations are given.

The relations between voltage, flux, magnetomotive force, current and torque in the d.c. machine are discussed in considerable detail in the first three chapters. There are some interesting sections which discuss where the torque acts on the stator or rotor when the conductors are in slots or in field coils. Further chapters deal with characteristics, losses, commutation and special machines. A final chapter headed Supplementary Matter examines several special points, and in

* LANGLOIS-BERTHELOT, R.: 'Electro-magnetic Machines' (Macdonald, 1953).

particular shows how the results deduced for the d.c. machine can be extended to apply to the a.c. machine.

It is a pity that the archaic word 'dynamo' is used in the title and elsewhere. At first the word seems to mean 'd.c. generator', which can also be used as a d.c. motor and has some features in common with an a.c. machine. However it appears on page 253 that a dynamo may be either a.c. or d.c. It would be better to use consistently the more precise terms 'electrical machine', 'generator' and 'motor'.

The topics selected for discussion are not always those of most importance in modern practice. For example, one of the principal modern applications of d.c. machines is for automatic control systems, for which separately excited generators and motors are usually required. The cross-field generator used as a rotating amplifier could best be discussed on its own merits, rather than as a modification of the constant-current generator. In general, the book does not demonstrate as much as it might that the subject of electrical machines is a thoroughly alive and rapidly developing branch of engineering, although it has been studied for over sixty years.

As a textbook for the undergraduate student the book is of a high standard on grounds of quality, but it may be criticized on grounds of quantity. It is generally agreed that a degree course for electrical engineers should be broadly based, ranging at least over the whole of 'electrical engineering' and preferably over the whole of 'mechanical sciences'. In a typical undergraduate course the proportion of time devoted to electrical machines as a whole is about 10%, and the subject matter of the book covers less than half of this field. There is too much detail for the needs of the undergraduate. For the practising engineer concerned with electrical machines, on the other hand, the book is very refreshing in bringing him back to a more fundamental viewpoint.

It should be noted that Professor Moullin has recently revised the text of his well-known book 'The Principles of Electromagnetism' for the publication of the third edition.* Many references to it are made in the text of his book on the dynamo, and the two books were in fact planned together as long ago as 1932. The new edition of the book on electromagnetism discusses, *inter alia*, the energy loss in a condenser having a conducting cylinder between its plates, the effective a.c. resistance of round wires and cylindrical coils, self-inductance of circuits, the magnetic force at the centre of an elliptical circuit, a conductor buried in an iron slab, circular and elliptical cylinders in uniform magnetic and electric fields. It also gives a large number of worked examples, some of which are taken from the examinations for the Mechanical Sciences Tripos at Cambridge University. Unquestionably this is an admirable book for the serious university student of electrical engineering's fundamentals.

J. G. THOMASON

LINEAR FEEDBACK ANALYSIS

PERGAMON PRESS. 365 PP. £2 15S.

There used to be two sorts of technical book, learned treatises which only a specialist could understand, and books for students or amateurs which conveyed very little solid information, and between the two there was a great gulf. Lately there has been a welcome tendency to issue books in which up-to-date and intellectually-satisfying methods are introduced in an intelligible manner, the sort of books from which the intelligent newcomer to some specialized field can learn much. 'Linear Feedback Analysis' is a worthy member of this new intermediate class. It does for feedback theory what Goldman's 'Transformation Calculus and Electrical Transients' does for transients and related topics, and Guillemin's 'Introductory Circuit Theory' for general network principles. Indeed, the engineer who wishes to gain a sound initial grasp of mathematical circuit theory cannot do better than nurture himself on all three.

Any new account of feedback must draw heavily from Bode's 'Network Analysis and Feedback Amplifier Design', and several chapters of Mr. Thomason's book are devoted to a lucid account of the central ideas of that classic but difficult work. Like Bode, the author finds it necessary to preface the main body of feedback theory with a general treatment of network principles, to give coherence to the whole. These introductory chapters give a good grounding in steady-state analysis, using complex exponentials, and in impulse analysis, using the Laplace transform. The relation between these two aspects of networks is made clear through the description of network functions in the complex-frequency plane, and the principles are illustrated by a judicious collection of examples, including a brief introduction to ladder filters (which could usefully have been extended by a few pages with material on the low-pass *LC* filter). The elementary but useful chapter on amplifying-stage design contains the well-balanced mixture of simple analysis, general principle and practical detail which recurs in the illustrative-design material later in the book.

After an introductory chapter giving a simple picture of feedback amplifiers, the book provides an analytical treatment of stability. Starting from a definition of a stable system as one with no increasing transients, and hence no poles with positive real parts, the author shows that amplifiers with one or two time-constants are inherently stable, while three time-constants may be stabilized by making one dominant. The relation between the transfer function and a loop-gain/phase plot leads to Nyquist's criterion for stability, and while the level of mathematical and conceptual difficulty unavoidably rises at this point, the transition is well bridged by a first introduction to complex-variable analysis. The latter topic is continued in the following chapter as far as Cauchy's theorem and Laurent's series, which lead to Bode's integral equations relating gain and phase, resistance and reactance. In Bode's book this culminates in the derivation of an ideal loop-characteristic to combine level gain in the pass-band with adequate phase margin outside. In Mr. Thomason's book this result is quoted and discussed, but not derived in detail.

Practical approaches to the desirable loop-characteristic receive a chapter, starting with the use of a dominant time-constant, and proceeding to the added complexity of phase-advance networks, but, rather surprisingly, omitting the use of filter impedances. The methods described are examined from all angles—a treatment helpful to the student—and the measurement difficulties and practical hazards (such as excess phase) which are mentioned serve as warnings to the inexperienced designer. Finally an assortment of practical designs are described, with the usual good mixture of principle and detail; they include differentiators, integrators and stabilizers as well as ordinary amplifiers.

The author's intention is 'to provide an analytical background for the young science graduate working in electronics or servomechanism research', and as far as the topics mentioned are concerned, this aim is accomplished. In many places he also conveys a good idea of the physical working and limitations of the circuits. The general arrangement and production are good, and the book can be recommended to those to whom it is addressed.

* OXFORD: CLARENDON PRESS. 446 PP. £2 5S.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

BOOKS

KEEN, A. W. 621.38

Electronics. An introduction for the non-technical reader and student to all aspects of electronics in this modern age of science*

London, Ward, Lock and Co., 1955. pp. 256. 21 × 14 cm. 25s.

An elementary but accurate and up-to-date account of electronic devices and the uses to which they are put. The descriptions are interesting and will be easily followed by anyone with a knowledge of elementary electricity and magnetism.

KIVER, M. S. 621.397.3

Color Television Fundamentals*

New York, McGraw-Hill, 1955. pp. vi, 312. 24 × 16 cm. 34s.

Introductory chapters deal with the colour-vision properties of the human eye, the principles of the N.T.S.C. colour system and the colour-video signal. A full colour receiver is discussed and each circuit analysed as to its purpose and operation. Then two American commercial models are described and details are given of a general servicing procedure for colour receivers.

KIVER, M. S. 621.397.62

Television and F-M Receiver Servicing*

3rd ed. New York, Van Nostrand, 1953. pp. iv, 320. 28 × 22 cm. 32s.

A practical book which discusses faults in television and f.m. receivers and methods of testing. American receivers are referred to but the book is of general help. This edition includes details of new circuits, otherwise the book is little changed.

LA TOISON, M. 535

Ultra-Violet Visible Infra-Rouge. Les lampes, sources de rayonnement et leurs applications pratiques.

Paris, Éditions Eyrolles, 1956. pp. 163. 24 × 16 cm. 30s. approx.

LESCH, G., and RACHEL, A. (Editors) 621.315.027.3

Die 400 kV-Forschungsanlage Rheinau. Teil I, Planung und Ausführung (The Rheinau 400 kV research plant. Part I, Planning and execution)

Heidelberg, 400 kV-Forschungsgemeinschaft e.V., 1955. pp. 157. 30 × 21 cm.

Describes the programme of research and development work which was started in 1950 and gives details of testing and measuring technique.

LITTLER, D. J., and RAFFLE, J. F. 621.039

An Introduction to Reactor Physics*

London, Pergamon Press, 1955. pp. viii, 196. 22 × 14 cm. 25s.

Gives sufficient explanation of the basic physics of the subject for an understanding of the principles involved in the construction of a reactor, then explains the calculations used in evaluating the critical size of a gas-cooled graphite-moderated natural-uranium reactor of the kind to be used in the Government's nuclear energy programme. Shielding, instrumentation and problems of structural material are discussed.

LOCKE, W. N., and BOOTH, A. D. (Editors) 413:681

Machine Translation of Languages. Fourteen essays*

New York, Massachusetts Institute of Technology, Wiley; London, Chapman and Hall, 1955. pp. xii, 243. 23 × 15 cm. £2 8s.

A collection of fourteen essays describing what has so far been achieved. Discusses some methods and general principles of mechanical translation including a design for an automatic Russian–English dictionary. Problems to be overcome before machines can be fed directly with the spoken or the printed word are explained and the types of storage devices available for a mechanical dictionary reviewed. Problems of interpretation, the multiple meaning of words and other complications of language are also considered. This book will be reviewed in a future issue.

LLOYD'S REGISTER OF SHIPPING 629.12

Rules and Regulations for the Construction and Classification of Steel Ships

London, Lloyd's Register, 1955. pp. 522. 29 × 25 cm.

Includes construction rules for electric propelling machinery and for electrical equipment.

C. LORENZ AKTIENGESELLSCHAFT 93:621.39

75 Jahre Lorenz 1880–1955

Stuttgart, C. Lorenz Aktiengesellschaft, 1955. pp. 272. 28 × 21 cm.

MAYSON, C. F. 347.7

Law and the Engineer. The law of contract and negligence as affecting engineers*

London, Chapman and Hall, 1955. pp. xx, 470. 23 × 15 cm. £3 3s.

A practical and understandable book by an author who is an electrical engineer as well as a lawyer. This book will be reviewed in a future issue.

MULLARD LTD. 621.318.32

Mullard Ferroxcube

London, Mullard Ltd., 1955. pp. 130. 26 × 21 cm. 7s. 6d.

Gives information on the mechanical, electrical and magnetic properties and applications of ferrites.

NAIRN, I. 71

Outrage (Reprint of the June, 1955, special number of the Architectural Review)

London, Architectural Press, 1955. pp. 94. 31 × 25 cm. 12s. 6d.

'Outrage' is a story of what is happening to the countryside, which, in spite of planning departments, is becoming festooned with hoardings, traffic signs, wires, pylons, etc., making it mediocre and ugly. The story is told mainly in pictures taken on a journey from Southampton to Carlisle and is intended to break down the apathy of the general public.

NEETESON, P. A. 621.396.615

Vacuum Valves in Pulse Technique*

Eindhoven, Philips' Technical Library, 1955. pp. viii, 170. 23 × 16 cm. 27s.

Indicates the methods of determining the behaviour of a network in which electronic tubes are used as switches. A considerable part of the book is devoted to multivibrators.

NIXON, F. E. 621–52

Principles of Automatic Controls*

New York, Prentice-Hall, 1953. pp. xi, 409. 22 × 15 cm. £3 15s.

Shows how automatic control systems can be defined mathematically and deals with transient response, frequency response, stability criteria, numerical integration and automatic computers. However only an elementary knowledge of the calculus and of physics is assumed. Discusses the Laplace transform, the Nyquist criterion, open-loop functions and the effects of noise and output disturbance.

SALT, L. E., and SINCLAIR, R. (Editors) 03

Oxford Junior Encyclopaedia Vol. 8 Engineering

London, Geoffrey Cumberlege, 1955. pp. xvi, 496. 25 × 20 cm. 30s.

One of twelve volumes intended as a basic reference work for school libraries and for the home. It is remarkably up to date and contains many interesting articles on all aspects of engineering. This book was reviewed in the Journal in November, 1955.

SCOTT, T. R. 621.314.7

Transistors and Other Crystal Valves*

London, Macdonald and Evans, 1955. pp. xvi, 258. 23 × 14 cm. £2 5s.

An account of the present state of development of crystal valves intended for the user rather than for those concerned with further developments. After dealing with crystal imperfections, p-n junctions, point-contact devices and operating conditions applications are described with details of circuits and testing techniques. This book will be reviewed in a future issue.

SHARPE, J. 621.318.572

Nuclear Radiation Detectors*

London, Methuen, 1955. pp. 179. 17 × 11 cm. 11s. 6d.

Explains the basic physical principles of the detector elements, dealing first with detection media and the efficiency of detectors, then describing secondary emission, and scintillation counters and ionization devices.

SMITH, K. F. 539.18

Molecular Beams

2nd ed. London, Methuen, 1955. pp. x, 133. 17 × 11 cm. 8s. 6d.

A new and enlarged edition of the original work by Dr. R. Fraser. It includes an account of the resonance apparatus, the technique of obtaining radio-frequency spectra, and the effects of magnetic and electric fields on atoms and molecules.

SOROKA, W. W. 518.5

Analog Methods in Computation and Simulation*

London, McGraw-Hill, 1954. pp. xii, 390. 24 × 16 cm. £2 13s. 6d.

Describes the operation of mechanical, electromechanical, electrical and electronic computing elements. Explains the functioning of analogue computers for linear simultaneous algebraic equations, polynomial equations and ordinary differential equations, including the mechanical differential analyser and the electronic analogue computer. Discusses the dynamical similarity between electrical circuits and mechanical systems and how equations for the one may be used for solving problems relating to the other.

STÖRMER, C. 551.593

The Polar Aurora

Oxford, Clarendon Press, 1955. pp. xvii, 403. 24 × 16 cm. £2 15s.

Auroral displays are caused by electrically charged solar particles which enter the earth's atmosphere at high levels, travelling along paths determined by their velocity and by the configuration of the earth's magnetic field. The author has, for many years, been concerned with the mathematical determination of these paths and with methods of measuring auroral heights and forms. The book describes also his observations of wireless echoes.

TAYLOR, E. O. (Editor) 621.31

Power System Plant*

London, Newnes, 1955. pp. xii, 307. 22 × 14 cm. 30s.

A series of lectures by well-known authors given at the Heriot-Watt College for advanced students and practising engineers. They deal with non-salient- and salient-pole type synchronous machines and their load, frequency and excitation control; with transformers, reactors and voltage regulators; with switchgear, underground cables and overhead lines.

THOMSON, Sir GEORGE 539

The Atom

4th ed. London, Geoffrey Cumberlege, 1955. pp. v, 204. 17 × 11 cm. 6s.

The present edition of this authoritative account includes a discussion of nuclear energy and of recent discoveries, including those relating to mesons.

VENABLES, P. F. R. 37

Technical Education. Its aims, organization and future development

London, Bell, 1955. pp. xii, 645. £2 2s.

A detailed account of the facilities available in this country for technical education by full-time, part-time and evening courses. Describes the qualifications which can be gained, the co-operation between educational establishments and industry, and university training. This book will be reviewed in a future issue.

VISSER, A. 413 = 00

Zestalig Technisch Woordenboek in Hoofdzaak Betreffende de Verreberichtgeving (Technical vocabulary in six languages principally adapted to telecommunications)

The Hague, Netherlands Postal and Telecommunications Services, 1955. pp. 778. 24 × 17 cm. £2 8s.

Dutch, French, English, German, Spanish and Italian with the vocabulary arranged alphabetically under the Dutch words and alphabetical indexes for each of the other languages.

WELSH, R. J., and WALLER, G. 621.438

The Gas Turbine Manual

2nd ed. London, Temple Press, 1955. pp. vii, 279. 22 × 14 cm. 30s.

A guide to modern practice excluding aircraft propulsion. Deals with first principles, design considerations, maintenance, and applications, and describes the latest British and foreign equipment.

YARWOOD, J. 533.5

High Vacuum Technique. Theory, practice, industrial applications and properties of materials*

3rd ed. London, Chapman and Hall, 1955. pp. viii, 208. 23 × 15 cm. 25s.

Describes the various types of pump now available, methods of getting rid of final traces of gases and the latest measuring techniques.

OTHER PUBLICATIONS

ODOK, A.

Zusatzverluste und Zusatzmomente in Kurzschlussankermotoren mit Unisolierten Stäben (Additional losses and torques in induction motors with uninsulated bars)

Zürich, Dissertationsdruckerei Leemann AG, 1955. pp. 75. 21 × 15 cm.

A thesis submitted for Doctor of Technical Sciences.

WELCH, S.

The Influence of Signal Imitation on the Design of Voice Frequency Signalling Systems

London, Institution of Post Office Electrical Engineers, 1953. pp. 16. 22 × 28 cm. 2s. 8d.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH FEBRUARY, 1956

£1 000 and over	6	6000 0 0
£100 to <£1 000	29	6386 3 0
£5 to <£100	779	8503 18 11
£2 to <£5	1878	5179 15 2
Under £2	19071	10035 16 11
		£36105 14 0

SCHOLARSHIPS

The Council invite applications for the following scholarships which are offered for award this year:

RESEARCH SCHOLARSHIPS

Ferranti	Value £500 p.a. for two years.
Oliver Lodge	Value £420 for one year; may be extended.
I.M.E.A.	Value £420 for one year; may be extended.
Swan Memorial	Value not exceeding £300 for one year.
C. P. Sparks Fund	Value £100 for one year.

GRADUATE SCHOLARSHIPS

Duddell	Value £400 for one year.
Silvanus Thompson	Value £400 for one year.

STUDENT SCHOLARSHIPS

**Duddell*	Value £200 p.a. for three years.
**Silvanus Thompson*	Value £200 p.a. for three years.
Paul	Value not exceeding £150 p.a. for four years.
Manville	Value £150 p.a. for three years.
Arthur Fleming	Value £120 p.a. for four years.
Salomons	Value £60 for one year.
David Hughes	Value £60 for one year.
Charles A. Parsons Memorial	Value £60 p.a. for three years.
Geipel	Value £50 p.a. for a period not exceeding four years.
Thorrowgood	Value £25 for one year.

The Geipel Scholarship is a new award and is available to students preparing for a career in the electrical supply or manufacturing industry.

The closing date for the receipt of application forms for the Student Scholarships is the 1st May, 1956, and for Graduate and Research Scholarships, the 1st June, 1956.

In special circumstances a candidate may be permitted to hold two awards concurrently.

APPOINTMENTS AND NOMINATIONS

BRITISH STANDARDS INSTITUTION TECHNICAL COMMITTEES

Committee on Electrical Glossaries and Graphical Symbols (ELE/9) [formerly Electrical Nomenclature and Symbols]

The Council have nominated Mr. L. H. A. Carr, M.SC.TECH., MEMBER, to serve as their representative on the above Committee in place of Professor J. Greig, M.SC., PH.D., MEMBER.

* The Duddell and Silvanus Thompson Scholarships will not be available as Student Scholarships if they are awarded as Graduate Scholarships.

Committee on Abbreviations and Letter Symbols (USM/2)

The Council have nominated Mr. L. H. A. Carr, M.SC.TECH., MEMBER, to serve as one of their representatives on the above Committee.

WEST MIDLANDS REGIONAL ADVISORY COUNCIL FOR TECHNICAL, COMMERCIAL AND ART EDUCATION

Electrical Engineering Advisory Committee

The Council have nominated Mr. D. A. Bell, M.A., B.SC., MEMBER, to serve as their representative on the above Committee.

COMMITTEE ON RADIO EQUIPMENT FOR CIVIL AIRCRAFT

On the nomination of the Radio Industry Council, the Council have appointed Mr. N. G. Anslow to serve on the above Committee in place of Mr. G. P. Parker, ASSOCIATE MEMBER.

COMMUNICATIONS FROM OVERSEA MEMBERS

Oversea members are specially invited to submit, for publication in the *Proceedings*, written communications on papers read before The Institution or published in the *Proceedings* without being read. The contributor's country of residence will be indicated. Brief articles or items of news intended for the *Journal* will also be most welcome.

Copies of all papers read before The Institution are sent to each Oversea Representative of the Council for distribution to members likely to be in a position to submit communications.

WRITTEN CONTRIBUTIONS TO DISCUSSIONS

Members who are unable to be present at a meeting, or who, if present, do not have an opportunity of speaking, may submit written contributions to the discussion which will be considered for publication in the *Proceedings*. This does not apply to Informal Meetings or Discussion Meetings.

We would also remind members that written contributions on papers published in the *Proceedings* without being read at meetings will be considered for publication.

Members should note that the Papers Committee have been obliged to set a limit of 300 words for contributions of either sort.

SEPARATES OF INSTITUTION PAPERS

The attention of members is drawn to the service by which The Institution provides individual copies of all papers (including monographs) published or republished in the *Proceedings*, which include the discussions of papers that have been read at meetings. Particulars of this service are given on page 181. Members who do not normally need copies of more than a few Institution papers each year may find that this service provides a more economical way of obtaining the required information, in a more easily storable form, than a subscription to a particular part of the *Proceedings*. The new binding cases announced in the January *Journal* are useful for storing a selected set of reprints so that they are quickly accessible.

GRADUATES AND STUDENTS SECTIONS

HENRY NIMMO PREMIUM

The Council have accepted a proposal from the members of the Southern Electricity Board to endow as a memorial to the late Mr. Henry Nimmo a premium for members of Graduates and Students Sections to be known as 'The Henry Nimmo Premium'.

The value of the Premium will be £10, to be awarded annually for the best paper on a subject coming within the field of Electricity Supply which is read before a Graduates and Students Section.

UTILIZATION SECTION SUMMER VISIT

11TH–13TH MAY, 1956

As previously announced, the Utilization Section Committee have arranged for this year's Section Summer Visit to be held at Harrogate from the 11th to 13th May, 1956. Details and application forms are being sent with this issue to all members of the Section.

INTERNATIONAL UNION FOR THE PROTECTION OF NATURE

The Council have received an invitation from the Chairman of the Nature Conservancy, Mr. Arthur S. Duncan, and the Chairman of the Society for the Promotion of Nature Reserves, Lord Hurcomb, to appoint an observer to the Fifth General Assembly of the International Union for the Protection of Nature at Edinburgh in June, 1956. The Council have accepted this invitation and invited Mr. Bryan Donkin, B.A., MEMBER, to attend the Assembly as The Institution's observer.

WORLD POWER CONFERENCE

VIENNA: 17TH–23RD JUNE, 1956

The general programme of the Fifth World Power Conference to be held in Vienna from the 17th to 23rd June this year is now available from the Secretary, British National Committee, World Power Conference, 201 Grand Buildings, Trafalgar Square, London, W.C.2. The programme comprises a complete time-table; hotel and travel information; an outline of the technical sessions; particulars of social events (including those specially for ladies), excursions and tours; a map of Austria; and various sketch plans. Membership of the Conference is open to all those having appropriate qualifications or holding responsible posts in British industries related to the subject-matter of the Conference. The British National Committee of the World Power Conference are presenting twenty-seven papers at the Vienna meeting, and a list of these can be obtained from the address above.

LEONARDO DA VINCI LECTURES FOR BOYS

Three Leonardo da Vinci Lectures, which are addressed to boys, will be given at The Institution of Mechanical Engineers during the Easter Holidays this year. The theme of the lectures is 'Energy in the Service of Man'. Particulars are as follows:

9th April, 1956 FUNDAMENTAL ENERGY
by Professor D. G. Christopherson, O.B.E., M.SC., PH.D.

10th April, 1956 APPLIED ENERGY
by Sir Claude Gibb, K.B.E., D.SC., M.E., F.R.S.

11th April, 1956 NUCLEAR ENERGY
by Sir Christopher Hinton, M.A., F.R.S.

Each lecture begins at 3 p.m. Admission is by ticket and these may be obtained gratis from the Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1. Applicants should enclose an addressed envelope and state the dates for which they require tickets.

A LECTURE ON CABLES

The Council of The Institution of the Rubber Industry announce that Dr. H. A. Daynes will deliver the Eleventh Foundation Lecture on 'Trends in Electric Cables made from Rubber and Plastics' at the Café Royal, Regent Street, London, W.1, on the 10th May, 1956, at 4 p.m. Tea will be provided before the lecture. All members of our Institution will be welcome, but admission will be by ticket only, obtainable from the Secretary, The Institution of the Rubber Industry, 4 Kensington Palace Gardens, London, W.8.

SCIENTIFIC INSTRUMENT MANUFACTURERS' ASSOCIATION

A PERMANENT EXHIBITION IN LONDON

A permanent exhibition of instruments manufactured by member firms of the Scientific Instrument Manufacturers' Association was opened at 20 Queen Anne Street, London, W.1, on the 9th February, 1956. The exhibition covers an entire floor of the building, which is the headquarters of the S.I.M.A. Although sufficient space is not available for all member firms to show their products at the same time, the exhibition is being arranged so that a representative selection of instruments will always be on view.

The exhibition is not intended to be public, but anyone interested in scientific instruments will be able to obtain admission; oversea visitors are particularly encouraged to inspect the exhibits. A full library of manufacturers' catalogues is being formed.

PORTRAIT OF AUGUSTIN FRESNEL

In accordance with its tradition of publishing, from time to time, portraits of the pioneers of communication engineering, the Union Internationale des Télécommunications has recently issued an etching of Augustin Fresnel, a reproduction of which is shown in the accompanying illustration. The pictures in this series, which are printed on art paper, measure 23 cm × 17 cm overall, and may be obtained from the Secrétariat Général de l'Union Internationale des Télécommunications, Palais Wilson, 52 rue des Pâquis, Geneva. The number of prints available of each portrait is limited to 700, and a small number of portraits of Ampère, Armstrong, Baudot, Bell, Erlang, Faraday, Ferrié, Gauss, Heaviside, Hertz, Hughes, Kelvin, Lorentz, Marconi, Maxwell, Morse, Popov, Pupin, Siemens, Tesla and Weber

are still available. The price (post free) of each of these portraits, including the recently issued one of Fresnel, is 3 Swiss francs.

ENGINEERING INSTITUTE OF CANADA

SPECIAL ARRANGEMENTS FOR THE WAIVER OF ENTRANCE FEES

The terms of the reciprocal arrangement between the Council of The Institution and the Council of The Engineering Institute of Canada for the waiving of entrance fees in some circumstances have recently been revised. This arrangement, which was first announced in the *Journal* in September, 1954, applies to members of one Institution when resident in the country of the other and elected to its membership.

The effect of the revision is to cover members of all grades and, in particular, Students of The Institution who might qualify as Junior Members in The Engineering Institute of Canada. The following is the revised arrangement.

No entrance fee will be payable

On election to The Engineering Institute of Canada, if the applicant

Is a member of The Institution in good standing, permanently resident in Canada, and makes application within twelve months of his taking up residence in Canada or, if already resident there, within twelve months of the first appearance of this notice.

On election to The Institution, if the applicant

Is a member of The Engineering Institute of Canada in good standing, permanently resident in Great Britain including Northern Ireland, the Isle of Man and the Channel Islands, and makes application within twelve months of his taking up residence in Great Britain or, if already resident there, within twelve months of the first appearance of this notice.

It has been agreed between the two Societies that where election to the host Society is in a grade of membership for which no entrance fee would in any case be payable, the oversea entrant shall, provided he is still a member in good standing of his mother Society, pay no entrance fee to the host Society when he is transferred to a higher grade of membership, irrespective of the time at which such subsequent transfer takes place, or of his grade of membership at that time in his mother Society.

QUALIFICATION FOR STUDENT MEMBERSHIP

Under Bye-law 16(*b*), the Council may allow candidates for Student Membership to defer, not later than the age of twenty-three years, the presentation of evidence of having reached a satisfactory standard of general education as denoted by the Common Preliminary Examination.

The Council have recently decided that they will not normally permit such deferment. As from the 1st April, 1956, candidates will ordinarily be required to have passed or gained exemption from the Common Preliminary Examination before election to Student Membership. The Council will continue to relax this rule if the circumstances are exceptional.

A CORRECTION TO THE *JOURNAL*

ARTICLE BY DR. WILLIS JACKSON, FEBRUARY 1956

In the second line of the Table on page 100 of the *Journal* for February, 1956, which formed part of Dr. Willis Jackson's article on the Education and Training of Russian Technologists, the period of study is given incorrectly as '6 years, 5 months'; this should be '5 years, 6 months'.

INTERNATIONAL HIGH-VOLTAGE CONFERENCE

SIXTEENTH MEETING OF C.I.G.R.É.

The sixteenth meeting of the International Conference on Large Electric Systems (C.I.G.R.É.) will be held at the Fondation Berthelot in Paris from the 30th May to the 9th June, 1956. Details may be obtained from the Secretary, C.I.G.R.É. British National Committee, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

DOMESTIC HEATING

A CONFERENCE IN MAY, 1956

The Institute of Fuel, with the co-operation of a number of interested societies, has organized a special study of 'Domestic Heating in the United Kingdom—Present and Future', which will open with a conference at Church House, Westminster, on the 1st and 2nd May, 1956. The papers will be published in advance and their presentation at the conference will be by summaries, thus allowing the maximum time for discussion, in which all attending will be invited to join. The meetings will be open, without charge, to the public to the limit of available accommodation, but those enrolling as members of the conference will have first call on the seats. The enrolling fee of one guinea will cover notices, programmes and a set of abstracts of the papers to be discussed, but not the full texts of the papers, which will be charged separately. Further details may be obtained from the Secretary, The Institute of Fuel, 18 Devonshire Street, Portland Place, London, W.1.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

SPECIAL ARRANGEMENTS FOR THE WAIVER OF ENTRANCE FEES

As a further development in the close and friendly relationship which has long subsisted between the two Societies, the Council of The Institution and the Board of The American Institute of Electrical Engineers have recently entered into arrangements whereby, in certain cases, no entrance fee will be payable when an applicant who is already a member of one is elected to membership of the other.

The following are the conditions under which the entrance fee will be waived:

On election to The American Institute of Electrical Engineers, if the applicant

Is a Corporate Member or Graduate of The Institution in good standing, permanently resident in the United States of America, and makes application within twelve months of his taking up residence in the United States or, if already resident there, within twelve months of the appearance of this notice.

On election to The Institution, if the applicant

Is a Fellow, Member or Associate Member of The American Institute of Electrical Engineers in good standing, permanently resident in Great Britain, including Northern Ireland, the Isle of Man and the Channel Islands, and makes application within twelve months of his taking up residence in Great Britain or, if already resident there, within twelve months of the appearance of this notice.

The two Societies hope that the introduction of these arrangements will lead to a further strengthening of the links which bind them.

POST-GRADUATE COURSES IN SCIENCE

UNIVERSITY OF LIVERPOOL: APRIL 1956

Three post-graduate courses are being arranged by the Department of Extra-Mural Studies at the University of Liverpool in April this year. The subjects and dates of the courses are:

Numerical Analysis and Digital Computing Machines (9th–13th April, 1956)

Fundamental Processes of Gaseous Discharges (8th–13th April, 1956)

Basic Principles of Nuclear Engineering (15th–21st April, 1956)

The lecturers for these courses include Professors J. D. Craggs, J. M. Meek and W. H. B. Skinner.

The first course is non-residential and the other two are residential. These courses are designed to provide information regarding recent developments in fundamental science which have important practical applications in industry. They are open to graduates and others of comparable qualifications in the appropriate field of study. Since the number of places available on each course is strictly limited, intending students should apply as soon as possible.

Application forms and full particulars may be obtained from the Director of Extra-Mural Studies, The University, 9 Abercromby Square, Liverpool, 7.

CONGRESS ON AUTOMATIC CONTROL

PARIS: 18TH–24TH JUNE, 1956

A meeting to consider various aspects of automatic control, including automation, will be held in Paris from the 18th to 24th June, 1956. Not only technical, but also economic and sociological, points of view will be considered, and an exhibition of automatic devices will be held concurrently. The congress is supported by the Société des Radioélectriciens. Further details may be obtained from the Secrétariat du Colloque sur l'Automatique, Chaire de Mécanique, Conservatoire National des Arts et Métiers, 292 rue Saint-Martin, Paris, 3e.

SUMMER SCHOOL IN SYSTEM PROTECTION

A Summer School in System Protection will again be held at the Borough Polytechnic, London, this year. The content of the course to be given will be very similar to that of last year's course, comprising mainly laboratory experiments on: system performance, including synchronous generators, transformers, fault calculation and arc phenomena; protective transformers (with reference to B.S. 2046); relays; protective systems; and arc suppression.

The period for the course is the 23rd July to 1st August, and the fee, which includes accommodation, board and tuition, is 15 guineas. Full details and application forms can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

THE ABC CONFERENCE, 1955

An 87-page report on the April, 1955, meeting of the ABC Conference on the unification of engineering standards has been published. The purpose of the Conference, which is held periodically between America, Britain and Canada, is to smooth out some of the small but highly important differences which still exist between British and North American practice in the design and manufacture of engineering fastenings. The Conference was first held in Ottawa in 1945.

Britain's delegation of 17 was organized by the British Standards Institution and led by Mr. Stanley Harley, Chairman of the B.S.I. Engineering Divisional Council, and the Conference was distinguished from previous ones by the presence of official observers from all the British Commonwealth countries. Mr. Harley said that the initials ABC might well be suited to the more modern concept of America and the British Commonwealth.

The attitude of many Commonwealth nations was voiced by Mr. Cyril A. Gladman of Australia, who said, 'Situated as we (in Australia) are at the cross-road between British and American practices . . . it is a matter of considerable importance to us that there should be some unification of techniques, practice and engineering standards amongst the English-speaking inch-using nations.'

The Conference dealt with unified screw threads, unified nuts and bolts, acme threads, microscope objective threads, gas-cylinder outlet threads, terminology, surface finish, limits and fits and miniature ball bearings.

Delegates were unanimous that future meetings of the Conference should be held more frequently; the interval between the present meeting and the preceding one, held in 1952, was too long.

Copies of the report are available from the Sales Branch, British Standards Institution, 2 Park Street, London, W.1, price 10s. each.

DISCUSSION MEETING ON TRANSFORMER LIMITS

COMMENT ON REPORT IN THE JANUARY *JOURNAL*

We have received a comment from a member on the report of the Discussion Meeting opened by Mr. R. A. Grierson on the 16th November, 1955, which appeared in the January *Journal* on pages 26 and 27. He points out that the sentence appearing in the last paragraph in the second column of page 27 that reads 'New transformer steels now available should stimulate trial runs at heavy overloads' is somewhat misleading. It appears that the point which was made at this stage of the discussion was in fact that new transformer steels would enable transformers with much better efficiencies to be supplied in place of transformers now in use, and as the economic life of the latter would thereby be considerably reduced, it might be possible to justify overloading some of them to shorten their remaining life.

We hope that this will clarify the report for other readers who may have been puzzled by this particular sentence.

STUDENTS' QUARTERLY JOURNAL

The contents of the March issue of the *Students' Quarterly Journal* include the following items:

'Electrification of Railways', by I. Bagdzinski.
'Nuclear Power', by J. K. Wood, M.SC.
'Resistance Strain Gauges', by H. Gill.
'A New Approach to an old Problem', by K. G. Fraser, B.SC.(ENG.).
'Telephone Transmission Systems', by K. W. Lee, B.SC.
'Testing and Maintenance of Insulating Oils', by A. Teague.
'Flight Instrumentation Engineering', by J. P. Bromley, B.SC.
'How to write a Technical Paper', by J. F. R. Williams.
'Electric Discharge Lamps', by B. M. Bird and R. F. Burbidge.
'Diesel-Electric Traction', by A. J. Barter, B.SC.(ENG.).
'Lightning Measurement and Protection', by T. I. Canning, B.SC. and W. M. Barron.
'High-Voltage Cable Practice', by N. Case, B.ENG.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 2nd January, 1956.

ELECTIONS

Member

DELORAINE, Maurice, DR.-ING.

Associate Members

BARRITT, John Derek, M.A., B.SC.
CLOTHIER, William Keith, B.SC., M.E.
CORBISHLEY, Ronald.
CURRY, William Kenneth.
HARKIN, James O'Donnell, B.A., B.E., B.SC.
HETHERINGTON, Arthur, B.A.
JAMES, Leslie Philip, B.SC.
KAGALWALA, Abid, M.E.E.
LAWS, William.
MARSDEN, Roderick Hudson, B.SC.
MYERS, Anthony Joseph.
NICHOLAS, Air Comm. Bryan David, C.B.E.
RAYNER, Capt. Christopher Stephen, B.SC.(ENG.), R. SIGNALS.
SHERRINGTON, William Marshall.
SIMPSON, William Rattray, M.A.
SMITH, Norman William.
THORPE, Henry Thomas.
TODD, Henry Philipson.

Associates

BALLARD, Lt.-Cmdr. Robert Humphrey, R.N.
COLLEY, Harold Norman.
GROVES, John Melville.
HALL, Alan George Moir.
PARKER, George Henry.
RODERICK, Evan Spurgeon.
WOODHEAD, Clifford.

TRANSFERS

Associate Member to Member

BROWN, Alexander Blair.
BUSS, Donald Arthur.
CAPELING, Leslie Frank.
FERGUSON, Ian Andrew.
FLUX, Robert William.
HORN, James Kawarau, B.E., M.SC.
HUGHES, Raymond Ernest.
MACFARLANE, John Crawford, B.SC.
McLAY, James, B.SC.
McLELLAN, Douglas Hay.
MARRYAT, Robert Anthony, B.SC.(ENG.).
MILLS, Ronald James.
MOFFATT, Charles Edward.
NEWHOUSE, Kenneth Henry.
RAMSAY, Alfred John.
RAO, Molahalli Sanjiva, M.A.
RICHARD, Bernard John.
ROBINSON, Alfred.

Associate to Associate Member

BIRKS, Harold.
EVANS, Colin Vaughan.
HARVEY, Richard, B.SC.
PANCHAL, Narotamdas Bhaichand.
STEPHENSON, Group-Capt. Clifton, R.A.F.

Graduate to Associate Member

ALCOCK, Bernard William.
ALDRED, Alec Sanderson, M.SC.
ALDRIDGE, Stanley Oliver, B.SC. (ENG.).
BAKER, John de Chair, B.SC.
BANDYOPADHYAY, Naba Kumar.
BARLOW, Eric Roxburgh.
BEAUCHAMP, Robert.
BECK, Harold Vincent, B.SC.
BENJAMIN, Capt. David Harewell.
BEZDEL, Wincenty, DIPL.ING.
BLACKWOOD, John Gordon, B.E.
BURTT, Keith Mennie, B.SC.(ENG.).
BUSSELL, Roy Sydney.
CARSON, Henry Laird, B.SC.
CHIPPENDALE, Harry, B.SC.
COOPER, Tom Gardiner.
COX, Raymond Samuel.
CROOKS, Ronald.
CUBITT, Noel Douglas.
DAVIES, David Martin, B.SC.
D'CRUZ, Joseph.
EVANS, Alfred.
FELTHOUSE, Arthur Roy.
FLETCHER, Peter Royle Charles.
FOSTER, Edward Norman, B.SC. (ENG.).
FURNISS, Robert Harry.
GAYNER, John Veale.
GILL, Frederick Whyatt, B.SC.TECH.
GOODY, Kenneth William.
HART, Peter.
HELLOWELL, Jack.
HOLT, Trevor, B.SC.(ENG.).
HOLTHAM, Aubrey Edwin James, PH.D., B.SC.(ENG.).
HUMPHREYS, Francis.
KING, John, B.SC.
KOLLER, Gerard Leo.
LAMERTON, Richard James, B.E.
LEWIS, Peter James, M.ENG.
McNAB, William Anderson.
McTAGGART, John, B.SC.
MAGUIRE, George Arthur, B.SC.
MALCOLM, Ian Leith.
MANIK RAO, Baloor, B.SC.(ENG.).
MELVILLE, James, B.SC.TECH.
MERRYLEES, Ronald.
MILLS, Harold.
MILLS, Robert Arthur, B.SC.
MOORE, Archibald Fisher, B.SC.
MORLEY, Ronald Henry, B.SC.(ENG.).
PARKER, Flt.-Lt. Gilbert Edward, B.SC., R.A.F.
PARKER, Peter Derek, B.SC.(ENG.).
PEACOCK, Gerald Page.
PETERS, Colin, B.SC.
POMIANKOWSKI, Stanislaw Kazimierz, B.SC.(ENG.).
POOLE, John.
PORTWAY, Anthony Gent, B.SC. (ENG.).
POWELL, Egbert Keith.
PRIEST, Peter Bruce, B.E.
PROWSE, Donald Windsor, B.SC.
RAMANATHAN, Kalyansundara, M.ENG.
REID, George Alexander, B.SC.(ENG.).
RICE, John.
ROBERTS, Gomer.
ROBERTSON, Donald Jackson, B.E.
ROBINSON, John Thurman, B.SC. (ENG.).
ROBISHAW, Wilfred.
ROWLEY, Leslie Raymond.
SASTRY, Cumbhakonam Swaminatha Padmanabha.
SCOTCHER, Edward Jesse, B.SC.TECH.
SCOTT, James Reid, B.SC.
SHAPLAND, Albert John.
SLATTERY, George.
SMITH, Algernon Fletcher, B.E.E
SMITH, John Vincent, B.SC.
SMITH, Kenneth Marchanton.
STOKOE, Lt. John Dumble, R.N.
SUDALL, Allan, B.SC.
TAIT, Thomas John.
TAYLOR, Kenneth.
THÉRY, Gilbert Auguste.
VAN OOSTEROM, Willem Hendrik, B.SC.(ENG.).
WHEELER, Stanley Arthur.
WILLIAMS, Claude, B.SC.
WILLIAMS, Nigel Arthur Frederick, B.SC.TECH.
WILLIAMSON, Alexander Joseph, B.SC.
WINDLEY, Roy, B.SC.(ENG.).
WINSTOCK, Jack Henry.

Graduate to Associate Member (contd.)

Student to Associate Member

AYERS, Peter Vernon.
GRAY, Major John Edward.

Student to Associate

THOMAS, David Lane, B.A.

The following elections and transfers approved by the Council are effective from the 5th January, 1956.

ELECTIONS

Graduates

ALDWORTH, Ernest Harold.
AMERY, Anthony Roy.
ARMSTRONG, Thomas Valentine, B.SC.
AUSTIN, Basil Roy.
BAKER, Donald Montgomery, B.E.
BALDWIN, Francis Henry, B.SC.
BARNES, Anthony Charles.
BARNFIELD, Rhydwyn William, B.SC.
BEAVERS, Arthur Augustus.
BEBBINGTON, Brian Walter.
BENNETT, Ronald William.
BIRBECK, Ralph.
BOORNE, John Hanson.
BOURNER, Hubert James.
BRINE, Pilot Officer Kenneth Charles, R.A.F.
BROWN, Dudley Francis.
BROWN, Eric Alfred William.
BROWN, Kenneth Harrison, B.SC., M.SC.
BROWNRIDGE, Norman Allan.
BRUNT, William David, B.SC.
BURMAN, Pannalal Jogesh, B.E.
BURNS, Peter.
CAMPBELL, Bernard Alexander.
CHANDLER, Peter.
CHAPMAN, Anthony John Cooper.
CHAPMAN, Kenneth Stanley.
CLARKE, Dudley John.
CLARKE, Geoffrey John.
CLEMENTS, Kenneth Thomas.
COOK, Arthur Roy.
COOK, Jeremy David, B.SC.(ENG.).
COOPER, Paul Duncan.
COOPER, Wallace George.
COOTS, Edward John, B.SC.(ENG.).
CORRY, Raymond.
COULTART, Ronald Clifford.
COWAN, Hugh Alan.
CRABTREE, Kenneth.
CRADDOCK, Frank Robert.
CROSSLEY, James Ernest.
CUMBERLAND, Raymond Stuart.
DARKIN, Keith Herbert.
DAVEY, Victor Stanley, B.E.
DAVIDSON, Colin William, B.SC.
DAVIES, David Gwynfor, B.SC.
DAVIES, Ronald George.
DAVIS, Alfred George.
DAVIS, Frederick John.
DEAR, Brian Michael.
DOBIE, William Cresswell.
DOUGHTY, Donald John.
DUCE, Gordon Enoch.
DUTTON, Gordon Philip.
EMPSON, Ronald.
EVERS, Alan Frederick, B.SC.(ENG.).
FIELD, Clarence Frederick, B.SC (ENG.).
FOSTER, Henry Thomas Vincent.
FRASER, Robert Murray, B.A.SC.
FYSON, John William.
GARRETT, John Harold.
GAUSDEN, Brian Herbert.
GEDDES, George Wood.
GINNS, Anthony Mark, B.A.
GLANFIELD, Dennis John.
GLOVER, Leslie.
GRAMLEWICZ, Stefan.
GREEN, Derrick Reid.
GROSS, Michael Hubert.
GUILD, William Sharp McCulloch.
HALE, Jack, B.SC.(ENG.).
HARMAN, Dennis Charles.
HARRIS, Pilot Officer Benjamin, R.A.F.
HARVEY, Sidney.
HASLAM, Fred.
HEDGECOCK, John William Arthur.
HESLING-GIBSON, Edward.
HODKINSON, William Ernest.
HOOPER, Samuel Brian David.
ILETT, Arthur Alan.
JACKSON, David Garth.
JACKSON, Robert John.
JAGGER, Sidney Henderson, B.SC.
JANIK, Wtadystaw Jo'zef, B.SC.(ENG.).
JILLINS, Frank Ernest.
JOHNSON, Herbert David.
JONES, Alfred.
JONES, David Leroy.
KEERS, Royce.
KENNEDY, John.
KERRY, Bernard.
LANCASTER, Eric.
LEE, Allan James.
LEE, David George.
LEE, Frank.
LEETHAM, Bernard Alfred.
LEVY, Allan.
LUTHER, Michael Anthony.
LYON, Peter Allwell.
McMAHON, Eric George.
MANNION, Reginald.

Graduates (contd.)

MAPLE, Bruce John.
MARKLEW, Alan David.
MARTIN, John.
MARTIN, William George.
MATTACKS, Peter Robert.
MAWBY, David Harry.
MITT, Hugo, B.E.
MOORE, John William.
MORRIS, Herbert Arthur.
MORRIS, Walter Newman.
MORRIS, William George.
NAYLOR, Gordon.
NAYLOR, Oscar Ernest O'Connor.
NESBITT, Joseph.
NEWMAN, Kenneth Edmund.
NG, Wing Yuen.
PADWICK, Trevor John.
PAGE, Roy James.
PALFREYMAN Alan Floyd.
PANVELIWALLA, Nariman Jamshedji, B.SC., B.SC.(ENG.).
PARR, William Stanley.
PARTINGTON, Kenneth Geoffrey.
PAVIE, John Arthur M.SC.
PHILLIPS, William Edward.
PIGGOTT, William Henry Ernest.
PITMAN, John Charles Kenneth.
POPPY, Henry.
PRICE, Graeme Athol, B.E.
REDPATH, James.
REED, John.
RICHARDSON, Roy.
RICKARD, Cyril Enoch George.
RILEY, Peter Verity, B.SC.
ROACH, Peter Francis.
ROBERTSON, Angus Drummond.
ROGERS, Raymond Arnold.
ROGERS, William Austin.
ROPER, Godfrey, B.SC.(ENG.).
ROSSITER, Peter Lyle, B.E.E.
ROTHWELL, Kenneth.
ROWE, Joseph Anthony.
ROWLEY, Gerald Edward.
RUMLEY, John Edward.
RUSSELL, David.
SADLER, Peter.
SALMON, Dennis Roy.
SANDS, Elijah Coburn.
SELLAR, Lennox Morrison.
SHELTON, Edwin.
SHEPHERD, Gwynn.
SHIRLEY, Eric Edward.
SIMPSON, Herbert.
SIMPSON, Michael Arnold.
SMART, David Leslie.
SMITH, Antony Derek.
SMITH, John Edward.
SPARKES, Donald Arthur.
SPENCE, Colin Black.
STEVENS, Ronald Thomas.
STEWART, John.
STREETS, John Harold.
SUMMERS, Ernest William.
TAIT, Alan George.
TAMIR, Theodor, B.SC., DIPL.ING.
TAYLOR, Kenneth Ronald Arnold.
TODD, Harold.
TUDOR-OWEN, Ronald Llewelyn Trevor, B.SC.(ENG.).
TURNER, Donald Cyril.
TURNER, Frederick Thomas, B.SC. (ENG.).
TURNER, Thomas Harry.
VIEL, Vernon Walter.
WALKER, James.
WARREN, Reginald Walter.
WHITEHOUSE, Geoffrey Eric.
WILKINS, Clive.
WILSON, Alan.
WOLSTENHOLME, Thomas Harvey.
WOOD, Bernard George.
WOODARD, Dennis Robert.
WOODS, Alexander Samuel.
WRIGHT, John Eric.
WYLDE, Gordon Stanley.
YOUNGE, Edward Ernest James, B.SC.

Students

ABERCROMBY, Thomas Stevenson.
ADAMSON, Robert Vaudrey.
ADJODAH, Shad Mukhlall.
AKHTAR, Khawaja Mohd Sultan, B.SC.
ARMITAGE, John Turner.
ATKIN, Graham.
AUSTIN, Christopher John.
BAKKENIST, Peter Allen, B.SC.
BALBES, Michael Stanley.
BARKER, Rolph William Johnson.
BASTON, David Arthur Leonard.
BEDDOW, Anthony James.
BOWDEN, Alan Leslie.
BOWEN, Kenneth Edward.
BOYLE, Peter.
BROOK, Donald.
BULLAR, David John.
BURTON, Thomas Roy.
BUTCHER, Derek.
CAPES, John Robert Hawksley.
CHAPMAN, David John.
CHOO, Seok Cheow.
CLARKE, Roger Wallis.
CLIFT, Ronald John.
CUBLEY, Robert William.
DANIEL, Idris John.
DATTA, Ranjit Kumar, B.SC.
DAWE, Geoffrey.
GODBER, Alan Sydney.
HACKNEY, Keith.
HASLER, Christopher.
HAYES, Raymond.
HAYWARD, Alan Arthur John.
HEATON, James Martin.
HILL, Valentine Benjamin.
HODGES, William Charles.
HOLDSWORTH, Charles Frederick.
HOUSLEY, Alan Thomas.
HOWIE, Robert Bruce.
INSTON, Herbert Henry.
JONES, Brian.
JONES, Henry Kelvin.
KAIL, Denis Harold.
KERKHAM, Andrew Harcourt.
KING, Arnold Raymond.
KINGAN, David Taylor.
KNIGHT, Robert Frederick Remus.
KUBBA, Muthanna Hussain.
LANE, David Arthur.
LANG, Robert Charles.
LEE, Ngian Tong.
LEVIN, Eliot Bernard.
LODGE, Alec John.
McCORMICK, Gordon Arthur Patrick.
McLARREN, Peter Grant.
MARSHALL, Robin Arthur.
MASTROYANNIS, Jean.
MELLING, John Alan.
MOFFAT, Gordon Henry.
MOON, Rudolph John.
MORRIS, Frank.
MYDUR, Nagappa, B.E.
MYERS, Brian.
NELSON, Philip Humphrey Hardwick.
NEVITT, Christopher Thomas.
NICHOLAS, Clive Harlow.
OLDROYD, David Brian.
OUTRAM, John Frederick.
PARKER, John Alexander.
PARKINSON, Kenneth.
PARROTT, Michael Frederick.
PIAT, Philippe Edouard Evenor.
PINEL, Alan Roy Grosvenor.
PO, Kenneth Chung Yee.
POPE, George Brian.
POTTER, Adrian Neil.
REGAN, Anthony.
RICHARDS, James Augustus.
ROBINSON, Ian Walker.
ROSE, James Kenneth.
ROUE, George.
SAMMONS, William Albert, B.SC.
SHEPHERD, Richard.

Students (contd.)

SINGH, Karam.
SMEDLEY, Clifford Frederick.
SPENCE, Charles Frederick Terence.
STEWART, Donald Fenwick.
THURSTON, Bryan Oliver.
TROTT, Alan Christopher.
TYLER, Michael John.
VAIDYA, Nandakumar Shridhar, B.SC.
WALKER, Hugh.
WARD, Haydn.
WATSON, Rex.
WEBBER, Anthony Ronald.
WEDDELL, Ronald Kenneth.
WELSH, Roger Ogg.
WERAGODA, Richard.
WHITE, John Kennedy Rose.
WHITEMAN, Donald Arthur.
WILD, Roger Howarth.
WILLIAMS, John Hywel
WILLIAMS, Richard Francis.
WILLIS, William David.
WILSON, Godfrey James.
WINTLE, Laurence.
WINYARD, Terence.

TRANSFERS

Student to Graduate

ADMASSIE, Betru, B.SC.(ENG.).
ALEXANDER, Frank Edward.
ANDREAE, John Hugh, B.SC.(ENG.), PH.D.
ANDREWS, David.
ASHMORE, Maurice Ralph.
ASHWORTH, Jack Marsden.
AYLING, Clifford Reginald, B.SC. (ENG.).
BAILEY, Graham John, B.SC.(ENG.).
BAILEY, Tom.
BAINES, Frank William Edward.
BAND, Colin Edward, B.SC.
BAXTER, William Henry.
BECKLEY, Alan.
BOSE, Bhanoo.
BOYLAND, Eric Charles.
BROOKS, Donald Peter.
BROWN, Kenneth John, B.SC.(ENG.).
BROWN, Norman James.
BURDEN, David Frederick.
BURLURAUX, Brian.
BURROWS, Ronald George Albert.
BUTCHER, John Anthony Weeks, B.SC.(ENG.).
BUXTON, Simeon Alan Earp.
CAMPBELL, James Martin.
CORLESS, Norman Fergie.
COULBECK, Edward Albert Byron.
COX, Peter.
CRAWSHAW, David Edmund.
CULLITY, Michael John.
DABROWA, Andrzej Roman, B.SC. (ENG.).
DAKIN, Christopher John, B.A.
DAVIES, John Royston.
DAVIES, Tom Ellis, B.SC.
DAVIES, William Alfred Clement.
DAVIS, Ronald.
DIXON, Norman.
DUNCAN, Alexander, B.SC.
DUNKERLEY, Robert Selwyn.
EVANS, Gwynfor Barrie.
FOSTER, William Henry.
FURSMAN, Raymond John.
GALLOWAY, George.
GALVIN, Peter.
GLEDHILL, David Leonard.
GRIFFITHS, Gerald.
GUEST, Brian Douglas.
GUHA, Prabir Kumar, B.SC.
HADDEN, Roger Griffiths.
HALL, Richard Oliver, B.SC.TECH.
HARDY, Roger Philip.
HEARN, Peter John.
HEINSON, Joseph Thomas.
HENDERSON, Frederick.
HIGGINS, Leonard James.
HIPKIN, Richard Charles, B.SC.(ENG.).
HOLTHAM, Peter Victor.
HOSKINS, Peter John.
HOULDING, Michael Alfred.
HOWE, Douglas John.
HURRELL, Frank Arthur.
JACKSON, Peter, B.SC.
JHA, Chandra Shekhar, B.SC.
JOHN, Haydn Graham.
JOHNSON, David Brook, B.ENG.
JOHNSON, Lewis Ralph.
JONES, Leslie Douglas.
KENNERLEY, William John Charles, B.ENG.
KNOWLES, Walter Brian.
LANCASTER, Kenneth, B.SC.(ENG.).
LEDBETTER, Alan Bradford.
LITTLE, John.
LUTHER, Christopher Alan.
LYNN, George Henry Camille.
McINERNEY, John.
MANSON, John.
MATHEWS, Geoffrey Stephen.
MILTON, Peter John.
MOSS, Frank.
MYERS, Eric Edward.
NICOL, James Somerville.
NYE, Anthony Edward Thomas, B.SC.(ENG.).
O'KELLY, Denis, M.SC.(ENG.).
ONYEWUENYI, Samuel Anele.
OPPENHEIMER, Rudolf, B.SC.(ENG.).
ORME, Derek, B.SC.
PARSONS, Peter Isaac James, B.SC. (ENG.).
PATEL, Manubhai Parbhubhai, B.SC.(ENG.).
PEARCE, George Arthur Edwin.
PEAT, Michael John.
PIKE, Kenneth Cecil.
PITT, Frederick Luckin.
PLUCKROSE, David Harold.
PLUMB, George Arthur.
POOLE, Stuart, B.SC.(ENG.).
REDMAN, Peter Frederick.
REYNOLDS, Albert James.
RICHARDSON, Colin Charles.
RICKETT, Thomas Walter.
ROACH, George William.
ROPER, Graham Buck, B.SC.(ENG.).
RUSSELL, Barry Lewis.
SHARP, Robert John, B.SC.(ENG.).
SIMPSON, Leonard.
SMITH, Clifford John.
SMITH, David Anthony Douglas, B.SC.(ENG.).
SMITH, James Cockburn.
SPENCER, Frank Hollis.
STEVENSON, John.
SWAN, Theophilus John Michael.
TASINI, Betsalel, B.SC.(ENG.).
TAYLOR, Donald James.
TELAHUN, Assefa, B.SC.(ENG.).
THOMAS, John Garnant, B.SC.
THOMAS, Raymond William, B.SC. (ENG.).
THOMPSON, Terence Michael.
THORPE, Geoffrey Kirkman.
TODD, Peter.
TUCKER, Ivor.
TUDOR, Ernest Rhodes.
TURNER, Robin Donald, B.SC.(ENG.).
VEREKER, Richard John Rawsthorn.
WALKER, Richard John, B.SC.(ENG.).
WALKER, William Neil.
WALSHE, Laurence Charles.
WARD, Arnold Andrea, B.SC.(ENG.).
WATKINS, Douglas Richard.
WATSON, John Cadman, B.SC.(ENG.).
WELLEN, Peter Antony.
WHITLOW, John.
WILSON, Richard George Thorp.
WOMBWELL, Alan Frederick.
YARNOLD, James Travers.

Elections and Transfers (*contd.*)

The following elections and transfers approved by the Council are effective from the 2nd February, 1956.

ELECTIONS

Graduates

ALLINGTON, Peter John Samuel, B.SC.
ATTWELL, John Dennis.
BARKER, Pilot Officer Sidney John, R.A.F.
BARLOW, James Alan.
BELL, Cyril.
BELL, Douglas, B.SC.(ENG.).
BENTICK, Julian Philip.
BERROW, Gordon Robert.
BHINGARE, Gajanan Jagannath, B.SC.
BOARDMAN, Frank Bryan, B.ENG.
BOOTH, Brian.
CAIRD, Allan.
CARR, John Wesley.
CARRINGTON, Stanley Bertram, B.ENG.
COPPARD, John Charles.
COX, Herbert Edward.
CROSS, Miss Catherine, B.SC.
CRUMP, Norman John.
CURTIS, William John Thomas.
DEACON, Michael John.
DENT, John Robson.
DUCK, Peter Martin, B.A.
FARROW, Leslie William John.
FRANKLAND, Eric.
GEDDES, John Downie.
GJERULDSEN, Erik, B.ENG.
GOODALL, John Latimer.
GRYGLASZEWSKI, Jerzy, B.SC.
HACKETT, John Thomas.
HANDS, Arthur Leslie, B.SC.(ENG.).
HARDCASTLE, Frederick William.
HEDDERLY, Pilot Officer John, R.A.F.
HILL, Clifford Louis.
HOWARD, Ernest James.
HOY, Frank David.
HUEY, Samuel Todd, B.SC.
HUGHES, Owen Idris.
IBRAHIM, Osman.
INGLE, Ronald.
JACKSON, Richard Norman.
JARVIS, James Arthur.
JOHNSTONE, Andrew.
JORDAN, Eric Nathaniel.
KEENE, Michael William.
KEMP, Charles Edwin David.
KIME, Frederick William.
KNIGHT, John Alfred Charles, B.A.
LEWIS, Peter Frederick.
LINTONBON, Charles Richard.
LLOYD, Brian, B.SC.
LLOYD, Julian Ralph John Alan, B.SC.(ENG.).
LOWRY, George Ross, B.SC.
MATTHEWS, Howard.
MAWER, Desmond Charles.
MOIZER, John Victor.
NAVOT, Israel.
NICOLL, Robert Joseph.
NOGUEIRA, Manuel Antonio de Araujo Morais.
OATES, Keith William.
OGILVY, Alexander William.
OLDFIELD, Ernest.
O'RIORDAN, Terence Patrick.
PADDISON, Elwyn.
PALLEMAERTS, Colin Julian Rupert.
PARKE, Fred.
PARROTT, Cyril Edward Bodley.
PICKUP, Frank.
PUDNEY, William Sidney.
REEVE, Gordon.
RICHARDSON, John McIntrye.
ROBERTS, Leslie Kenneth, B.SC.
ROBINSON, Alan.
ROE, John Davison.
SENESCALL, Derek Albert.
SEYMOUR, Robert.
SHALLOW, Peter George Dawson, M.A.
SIMMONDS, Frederick David.
SIMPSON, Herbert.
SIPPINGS, Dennis Jack.
SKINNER, Michael John.
SMITH, Edward.
SMITH, Robert Alan.
SOUTAR, Douglas.
SPICKETT, John Francis.
STEPHENSON, Bryan Edgar.
STEWART, Robert James, B.SC.
STOCKING, Donald Thomas.
STONE, Graham Thomas.
STRINGFELLOW, John Francis, B.SC.
SUTHERS, Michael.
THOMAS, Henry David.
THORN, Waldo.
THORNLEY, John Stanley Thomas.
TICKLE, Bertram Francis.
TRICKETT, John Alexander.
TURNER, Francis William.
TURNNIDGE, Peter Edward.
ULRICH, Herbert Stewart Lawrence.
WATERWORTH, John Colin.
WHITE, Norman Leslie, B.SC.(ENG.).
WILLISON, William Ernest.
WORTHINGTON, Pilot Officer David Robert, R.A.F.

Students

ADAMSON, Allan Nicoll Gordon.
AGARWALA, Ram Niranjan, B.SC.
AHMED, Haroon.
ALLCORN, Kenneth Walter.
ANI, Isaiah Nnamani.
AROR, Blackie Ighovberhai.
ATKINSON, Denis Vivian.
BAILEY, Thomas Alun.
BENN, Charles Brian.
BHANDARI, Man Mohan.
BICKERSTAFFE, Ronald Stanley.
BIRD, Simon.
BLISS, Eric Morley.
BLYTHE, Richard Wilmot.
BOARDMAN, Colin.
BRADLEY, Colin Roland.
BRECKNELL, Geoffrey William Jackson.
BRETT, Robert Frank.
BROSNAN, Daniel Paul.
CAREY, Peter Majendie.
CASHMORE, Brian Howe.
CHALLENGER, Michael Trevor.
CHOUDHURY, Ratindra Mohan Roy.
CONDLIFFE, William Harvey.
CORRAN, Eric Robert.
CULLIMORE, Peter Anthony.
CURRIE, George Alisdair Cockburn.
DE MELLO, Peter Donald Joseph.
DEVENISH-MEARES, Basil Leycester.
DIKKO, Yahaya Abdurrahman.
DUTT, Ratan Bikash, B.SC.
EDWARDS, David Michael.
FARID, Mohamed Abu Zaffar.
FARMER, William Trevor James.
FINCH, Douglas Harold.
FITZROY, David.
FRAMPTON, Richard William.
GALE, Robert David.
GALLOWAY, Fred.
GASKILL, Charles David Sinclair.
GRIFFITHS, Peter.
GUNASEKERA, Noel Clarence.
HARMAN, Charles Arthur.
HEMANS-MENSAH, Henry Mark.
HICKSON, Martyn Galloway.
HOWARD, Frank David.
HUGHES, Michael Thomas George.

Students (contd.)

HUSSON, Georges.
ILLINGWORTH, Lewis.
JACKSON, John David.
JAKEMAN, Peter Norman.
JOHNS, Maurice Stephen Ablitt.
JONES, Llewelyn Robert.
KENNEDY, John Roger.
KNIGHT, Ronald Walker.
KNOWLES, James Brian.
KURI, Kula Bhusan, B.E.
LEAKE, John Walgate.
LEAMAN, Kenneth Arthur.
LINES, Denis.
LLOYD, Raymond Michael.
LOTA, Surjit Singh.
LOTT, Brian.
McNALLY, Donald.
McNEILL, Alexander.
MARSH, Antony Herbert.
MATHER, Brian.
MATTINGLY, Peter Henry, B.SC.
MEE, David Geoffrey.
MORGAN, Stanley.
NUNNS, David.
PANCHAL, Chandrakant Narbheram.
PARTRIDGE, Simon Godfrey.
PAYNE, John Malcolm, B.A.
PEEBLES, Ronald Edward.
PEPLOW, James Ernest John.
QUIROGA-PINEYRO, Luis Fernando.
RALEY, Geoffrey Arthur.
RANGWALLA, Abdul-Husein Abdul-Tayeb, B.SC.
REES, Ian Marsh.
RIDDEL, John Michael.
RILEY, Malcolm Masterton, B.SC.
ROBINSON, Christopher Reginald.
ROBINSON, Peter.
ROY, Amitava Dutta, B.SC.
SALTHOUSE, Edward Charles
SHAH, Harshavadan, B.SC.
SHAH, Shantilal Maganlal, B.E.
SHARMA, Coimbatore Ramakrishnan Padmanabha, B.SC.
SHARPE, John Thomas Lawrence.
SHAW, Frank Derek.
SIMPKIN, Stanley.
SMITH, Edgar Laurence.
SMITH, Owen Compton.
SOOSAIPILLAI, Anton Manoretnam, B.SC
STEELE, Lt. Peter Michael, Royal Signals.
STINSON, John Keith.
STOCKWELL, Roger John.
STOLL, Richard Leslie.
SURMAN, Colin Roger.
TANEJA, Prem Dayal, B.SC., B.E.
TAYLOR, Gavin.
THOMPSON, Alexander.
THOMPSON, David Jardine.
THORNEYCROFT, Malcolm.
TOWERS, Alfred Norman.
VAN DER WEYDEN, Paul Romer.
WADE, Brian Newman.
WALSHAM, Edward Alec.
WARD, Christopher John.
WHITING, George Benjamin.
WILLIAMS, Brian.
WILLIS, Desmond Bryan.
WISTOW, Eric.
WOLLASTON, Brian Robert Major.
WONG, Ming Yap.
WOOD, Leonard George.
WOODHEAD, Robert Barton.
WRIGHT, John Peter.

TRANSFERS

Student to Graduate

ABBOTT, David Arthur, B.SC.(ENG.).
AKINDELE, Theophilus Olu.
ALDERTON, John Raynham.
BEDI, Sarjit Singh.
BENTLEY, Peter Noel.
BISWAS, Sushil Kumar.
BOOTH, Alfred Ernest.
BOOTH, Richard Lewis, B.SC.(ENG.).
BOUVET, Jean.
BUCKLAND, Peter Alan Muschamp D'Assis.
BUTLER, John Charles.
CARNEGIE, Peter Brisbane.
CHADWICK, Jack.
CORBEN, Brian George.
DAVIES, Raymond John.
DELLOW, Charles Henry Carley.
DOLAN, Michael John.
DUCK, Edwin Walter, B.SC.(ENG.).
ENGLISH, Ernest Robert George.
FILLER, Edward Albert.
FOULKES, Sec.-Lt. John Edward.
GUHA, Kumud Ranjan, B.SC.
GWAL, Ramphal Badluprasad.
HARKNESS, John Alan.
HARRIS, Lionel Arthur, B.SC.(ENG.).
HARVEY, John Michael, B.SC.(ENG.).
HAY, Alan Strickland, B.SC.
HAYES, Kenneth Henry.
HOOPER, John Robert, B.SC.(ENG.).
HOUSTOUN, John, B.ENG.
HUSSEY, Lt. Reuben Theodore, B.SC.(ENG.).
IBUKUN, Lawrence Olu, B.SC.(ENG.).
IRVING, Michael John.
JONES, Brian William.
KING, David John.
KLESEL, Michael Oliver.
LAIDLAW, Thomas Ramsay, B.SC.
LAMPORT-STOKES, Peter George Herbert, B.SC., B.A.
LAND, George Derek, B.A.
LEAVER, Robin Henry.
LORTON, Peter Ronald.
McMILLAN, Keith Henry Douglas, B.SC., B.SC.(ENG.).
MA, Ying Ping, B.SC.(ENG.).
MAH, Seck Wah.
MERRICK, Arthur Bruce.
MIDDLETON, John Francis, B.SC. (ENG.).
MITCHELL, Bernard George.
MORRISON, Patrick Richard.
PAMPOUCAS, Timoleon Vlassios Demetriou, B.SC.TECH.
PARISH, Leslie Alexander.
PHILLIPS, Vivian Jones, B.SC.(ENG.).
POLIN, Bryan Matthew George.
PRESCOTT, Trevor.
RAINFORD, Maurice Vernon.
RAMASAMY, Venkateswaran.
READ, Kenneth George.
RELTON, Joseph Warbrick, B.ENG.
RIDLEY, Kenneth Albert.
SAUNDERS, Derek Lionel, B.SC.(ENG.).
SOOD, Satish Chandar, B.SC.(ENG.).
STIFF, John Raymond.
STUART, Malcolm Archibald.
URQUHART-PULLEN, David Ian, B.SC.(ENG.).
WALKER, John Graham.
WALLIS, Alan Douglas.
WHITEHEAD, Eric.
WILLIAMS, Alan Mark.
WINSTANLEY, Eric Joseph.

OFFICERS OF THE INSTITUTION

PATRON: H.M. THE QUEEN

Council, 1955–56

PRESIDENT — SIR GEORGE H. NELSON, BART.

PAST-PRESIDENTS — SIR JAMES SWINBURNE, BART., F.R.S.
W. H. ECCLES, D.SC., F.R.S.
THE RT. HON. THE EARL OF MOUNT EDGCUMBE, T.D.
J. M. DONALDSON, M.C.
PROFESSOR E. W. MARCHANT, D.SC.
P. V. HUNTER, C.B.E.
H. T. YOUNG
SIR GEORGE LEE, O.B.E., M.C.
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All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**R**	RADIO AND TELECOMMUNICATION SECTION
I	INFORMAL	**S**	SUPPLY SECTION
M	MEASUREMENT AND CONTROL SECTION	**U**	UTILIZATION SECTION
O	ORDINARY		

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.
Particulars of **District Meetings** are given on page 204.

MARCH

16 *Friday* — Radio and Measurement Sections Dinner-Dance (at the Café Royal, at 7 for 7.30 p.m.) — **R and M**

19 *Monday* — Informal evening on 'Electronics and Automation', at which there will be a talk (with films and demonstrations) on 'Some Industrial Applications' given by H. A. THOMAS, D.SC.† — **R and M**

21 *Wednesday* — G. F. KENNEDY, M.A. Informal Lecture on 'American Power Station Practice'‡ — **S**

27 *Tuesday* — E. FRANKLIN, M.SC.(ENG.), PH.D., *and* J. B. JAMES — **M and R**
'The Applications of Transistors to the Trigger, Ratemeter and Power Supply Circuits of Radiation Monitors' (Paper No. 2049 M)‖ *Synopsis:* February 1956

† An abstract of the introduction will be available in advance.
‡ A synopsis will be available in advance.

This paper has now been published individually (see p. 181).

G. B. B. CHAPLIN, M.SC., PH.D.
'A Point-Contact Transistor Scaling Circuit with 0·4 microsec Resolution' (Paper No. 2064 R)‖ *Synopsis:* See page 183

G. B. B. CHAPLIN, M.SC., PH.D., *and* A. R. OWENS, M.SC.
'A Junction-Transistor Scaling Circuit with 2 microsec Resolution' (Paper No. 2076 R)‖ *Synopsis:* See page 181

APRIL

4 *Wednesday* — Symposium of papers on the Crystal Palace Television Station. (**At 6.15 p.m., tea at 5.45 p.m.**) **R**

F. C. MCLEAN, C.B.E., B.SC., A. N. THOMAS *and* R. A. ROWDEN, B.SC.(ENG.)
'The Crystal Palace Television Transmitting Station' (Paper No. 2069 R)§ *Synopsis:* See page 183

A. R. A. RENDALL, PH.D., B.SC., *and* S. H. PADEL, B.SC.
'The Broadcasting House–Crystal Palace Television Link' (Paper No. 2072 R)§ *Synopsis:* See page 183

V. J. COOPER, B.SC.(ENG.), *and* W. J. MORCOM, B.SC.(ENG.)
'Band I Television Transmitter Design with particular reference to the Transmitters at Crystal Palace' (Paper No. 2075 R)§ *Synopsis:* See page 183

5 *Thursday* — An Ordinary Meeting taking the form of a meeting of the British Nuclear Energy Conference. For details of the papers to be read, etc., see under **British Nuclear Energy Conference** on page 203 **O**

9 *Monday*–**14** *Saturday* — Convention on Digital-Computer Techniques. See page 204 **M and R**

16 *Monday* — K. L. MAY will open a discussion on 'Inspection and Maintenance of Wood Poles'* **I**

17 *Tuesday* — F. C. WIDDIS, B.SC.(ENG.) **M**
'The Indirectly Heated Thermistor as a Precise A.C.-D.C. Transfer Device' (Paper No. 1989 M)‖ *Synopsis:* February 1956

A. M. THOMPSON, B.SC.
'A Bridge for the Measurement of Permittivity' (Paper No. 1963 M)‖ *Synopsis:* December 1955

19 *Thursday* — J. J. BATES, PH.D., *and* PROFESSOR A. TUSTIN, M.SC. **U**
'Temperature Rises in Electrical Machines as Related to the Properties of Thermal Networks' (Paper No. 2026 U)‖ *Synopsis:* See page 182

PROFESSOR A. TUSTIN, M.SC., *and* J. J. BATES, PH.D.
'Temperature Rises in Electrical Machines on Variable Load and with Variable Speed' (Paper No. 2031 U)§ *Synopsis:* See page 182

PROFESSOR A. TUSTIN, M.SC., D. F. NETTELL, B.SC., *and* R. SOLT, B.SC.(ENG.)
'Performance and Heating Curves for Motors on Short-Run Duties' (Paper No. 2036 U)§ *Synopsis:* See page 182

20 *Friday* — PROFESSOR G. W. CARTER, M.A., will open a discussion on 'Theories of Electromagnetic Induction'* (At 6 p.m., tea at 5.30 p.m.) **E**

23 *Monday* — Informal evening on 'Electronics and Automation': there will be a talk (with films and demonstrations) on 'Automatic Assembly Systems for Electronic Equipment' by G. W. A. DUMMER, M.B.E.† **R and M**

25 *Wednesday* — H. C. HALL, M.SC., *and* E. KELK, M.SC. **S and M**
'Physical Properties and Impulse Strength of Paper' (Paper No. 2024 S)§ *Synopsis:* See page 181

H. C. HALL, M.SC., *and* D. J. SKIPPER, B.SC.(ENG.)
'The Impulse Strength of Lapped Impregnated Paper Dielectric' (Paper No. 2025 S)§ *Synopsis:* See page 181

W. G. STANDRING, M.A., *and* R. C. HUGHES, B.SC.
'Breakdown under Impulse Voltages of Solid and Liquid Dielectrics in Combination' (Paper No. 2050 S)§ *Synopsis:* See page 182

26 *Thursday* — PROFESSOR A. C. B. LOVELL, O.B.E., PH.D., F.R.S. **O**
The Forty-Seventh Kelvin Lecture on 'Radio Astronomy'*

27 *Friday* — SIR MAURICE BOWRA, F.B.A., M.A.
Second Graham Clark Lecture on 'The Impact of Engineering on Society'* (Joint meeting with The Institutions of Civil and of Mechanical Engineers at The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, S.W.1.) Admission by ticket only, obtainable from the Secretary, The Institution of Mechanical Engineers.

30 *Monday* — The President will open a discussion on 'The Efficient Use of Technical Personnel'* **I**

* No advance information will be available.
† An abstract of the introduction will be available in advance.
§ This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published individually (see p. 181).

British Nuclear Energy Conference: Forthcoming Programme

MARCH

20 *Tuesday*

A meeting sponsored by The Institution of Chemical Engineers will be held at The Royal Institution, Albemarle Street, W.1, at 5.30 p.m. (tea at 5 p.m.). No tickets of admission are required. The following paper will be presented and discussed.

J. B. MORRIS, PH.D., C. M. NICHOLLS, B.SC.(ENG.), *and* F. W. FENNING, B.A.
'The Application of Fluidization Techniques to Nuclear Reactors'

Advance copies of the paper will be available from the General Secretary, The Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1; applications for these should include a stamped addressed label or envelope (preferably 9 in. × 6 in.). For a synopsis of the paper see the February *Journal*, p. 122.

28 *Wednesday*

A Symposium on Nuclear Energy will be held at The Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1, at 3.00 p.m. The Symposium will be opened by the President of The Institution of Mechanical Engineers, Mr. P. L. Jones, M.C., B.SC., WH.EX. There will be an interval for tea at 5 p.m. Admission will be by ticket only, obtainable from the Secretary of The Institution of Mechanical Engineers. The titles and synopses of the papers to be read and discussed are given below. Applications for advance copies of the papers should be addressed to the Secretary of The Institution of Mechanical Engineers and should be accompanied by a stamped addressed envelope (preferably 9 in. × 6 in.).

PROFESSOR JACK DIAMOND, M.SC., WH.SC., *and* W. B. HALL, B.SC.(ENG.)
'Heat Removal from Nuclear Power Reactors'

The authors describe the general problem of heat removal from nuclear power reactors in which the fuel elements are in the form of solid rods or bars. The energy released in the fuel must be transferred to a coolant by forced convection, and, for power cycle efficiency, it should preferably be transported from the reactor by the coolant at a temperature as close as possible to the maximum permissible fuel temperature. The influence of the coolant physical characteristics and of fuel-element extended surfaces on the maximum coolant temperatures and on pumping power losses for a given heat-removal rate are discussed, and gaseous and liquid coolants are compared. Simple methods are suggested for a first analysis of the heat-transfer aspects of a reactor cooling problem and are demonstrated by an example in gas cooling.

B. L. GOODLET, O.B.E., M.A.
'Nuclear Reactors for Power Generation'

The paper is intended to be an educative introduction to the problems encountered when attempting to design nuclear reactors for power generation. It is based on five years' work in this field. Part I formulates various problems of reactor technology under the headings reactor physics, reactor materials, radiation and radioactivity, and engineering design. In Part II an attempt is made to show how various kinds of reactor—fast, pressurized and boiling-water, and graphite-moderated—arise naturally from application of the elements of reactor theory and reactor technology. Part III deals with the running control of nuclear power plant.

The appendix, on reactor theory, should really be read before the paper. It is an attempt to summarize, in language comprehensible to engineers, the basic physics on which reactor operation depends.

C. E. ILIFFE, M.A.
'Shielding against Nuclear Radiation'

Mr. Iliffe first describes the characteristics of neutron radiation and the concepts of cross-section, flux and current density are defined. Fick's law of diffusion as applied to neutrons then leads readily to the two-group theory of neutron diffusion as used in reactor theory, together with the additional concepts of diffusion slowing-down and extrapolation lengths. The shortcomings of the two-group theory in shielding problems are emphasized.

The properties of gamma rays and the ways in which they may arise are next discussed. It is shown that the concepts of cross-section, flux and current density are still applicable but that the diffusion treatment as described for neutrons must be replaced by one in which primary gamma rays, which have so far escaped interaction with matter, are multiplied by a build-up factor to arrive at the effective radiation. A brief reference is also made to alpha and beta particles and fission fragments.

The next part of the paper deals with the generation of gamma radiation, both that arising from neutron capture, and from the radioactive decay of fission products or neutron-activated materials. Tables are given of the radiation emitted by various materials due to any of these causes.

The maximum permissible level of radiation is then introduced, and the concept of shielding by distance referred to. Mr. Iliffe describes the shielding of a nuclear reactor, taking the Windscale thermal reactor as an illustration, and the general case of radiation from a reactor coolant circuit is investigated. The paper concludes with a discussion of heat generation in shields and of likely future developments.

R. E. ZOLLER, B.SC.(ENG.)
'Steam Cycles and Nuclear Power Plant'

The author considers the use of several reactor-core coolant media, and suitable single- and multi-pressure steam cycles for various reactor systems are discussed. Where the power consumption for circulating the coolant may be appreciable, the selection of the optimum operating condition for certain power reactors is illustrated. Methods of avoiding excessive moisture in the turbine exhaust which are particularly applicable to water-cooled reactors are suggested. It is

* All meetings are open to members of the five constituent bodies of the Conference, but for certain meetings tickets of admission are required.

'Steam Cycles and Nuclear Power Plant' (*contd.*)

recommended that, with those reactor power plants limited to low coolant temperatures, the use of separately fired superheaters should be given careful consideration, in view of the high utilization efficiency of the oil fuel and the very low initial capital cost of the resulting additional station capacity.

APRIL

5 *Thursday*

A meeting taking the form of an Ordinary Meeting of The Institution will be held at Savoy Place at 5.30 p.m. (tea at 5 p.m.). No tickets of admission are required. The following papers will be presented and discussed:

A. B. GILLESPIE, B.SC.
'The Control and Instrumentation of a Nuclear Reactor'*

R. J. COX, B.SC., *and* J. WALKER, M.A.
'The Control of Nuclear Reactors'*

W. ABSON, B.SC., *and* F. WADE
'Reactor Control Ionization Chambers'*

G. E. LOCKETT
'Some Design Aspects of Nuclear Reactor Control Mechanisms'*

Advance copies of these four papers will be available from the Secretary, The Institution of Electrical Engineers, by the 26th March.

12 *Thursday*

A meeting taking the form of a meeting of the Public Health Division of The Institution of Civil Engineers will be held in the building of The Institution of Civil Engineers, Great George Street, S.W.1, at 5.30 p.m. (tea at 5 p.m.). No tickets of admission are required. The following paper will be presented and discussed:

W. L. WILSON, O.B.E., B.SC.(ENG.), P. A. F. WHITE, B.SC., *and* J. G. MILTON
'The Control, Conveyance, Treatment and Disposal of Radioactive Effluents from the Atomic Weapons Research Establishment, Aldermaston'

The authors state that the principles adopted for dealing with radioactive waste at Aldermaston were developed from those originally devised for and used at the A.E.R.E., Harwell, and shows how attempts were made to overcome certain limitations that became evident there. It sketches these limitations and describes the solutions adopted.

A description of the research that was undertaken to determine the form of the effluent-treatment and distillation plant shows the approach which led to the type of plant and its required performance. The authors give the types and costs of chemical additives examined and state the final results. The full-scale plant is described in detail together with particular additional developments, primarily those dealing with the safe 'canning' of active sludges. The authors describe the works at and in the River Thames together with an outline of the special trials.

Advance copies of the paper will be available from the Secretary, The Institution of Civil Engineers.

MAY

3 *Thursday*

A meeting sponsored by The Institution of Chemical Engineers will be held at the Royal Institution, Albemarle Street, W.1, at 5.30 p.m. (tea at 5 p.m.)

H. G. DAVEY, O.B.E., M.SC.
'Some Problems in the Maintenance of Nuclear Reactors'

When the Windscale reactors were being designed it was assumed that after they went on to power those parts which had been subjected to radiation could not be maintained. Therefore, a fundamental concept of design was, as far as possible, to make the reactor itself static and to keep moving parts outside the biological shield. For example, as the reactors were air-cooled, the air had to be either pulled or pushed through the reactor, and pushing was chosen because this meant that the large fans would remain inactive and not become contaminated and, therefore, would be subjected to normal maintenance.

Over a period of time those items contained within the reactor proper, which have been subjected to the influence and effect of flux, temperature and air flow, have developed faults and thus unusual and to some extent unexpected maintenance work has had to be done under reactor conditions. As each problem was novel, special techniques had to be evolved to carry out what were in themselves simple mechanical operations but which were rendered difficult by the unusual circumstances and the hazards.

The paper gives examples of the work which has been done, the special techniques which have been evolved for doing the work and the precautions which have been taken to ensure that the personnel engaged on this work were not contaminated and did not receive radiation doses in excess of the limits laid down by the Medical Research Council.

After five years' operating experience the author is satisfied that, given certain facilities and by following the techniques which have now been evolved, a reactor can be made maintainable; this will have a fundamental effect on the design of future reactors.

JULY

3 *Tuesday to* 6 *Friday*

A Conference on the Physics of Nuclear Reactors, sponsored by The Institute of Physics. This will take place in the building of our Institution. Some tickets for the Conference have been allocated to our members, and those who are interested should write immediately (on a postcard) for particulars of the Conference and an application form to the Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1. The programme will be published in next month's *Journal*.

* For synopses of these papers see pages 182–3.

Convention on Digital-Computer Techniques, 9th–14th April, 1956

Measurement and Control Section : Radio and Telecommunication Section

A programme of the Convention on Digital-Computer Techniques, which includes particulars of arrangements, is being sent to all those who have registered for the Convention. The following is a list of papers that will be presented at the Convention; the individual publication of a few has already been announced in the *Journal* and the remainder will be published shortly before the Convention. It is probable that a few additional papers not shown in this list will be included in the final programme. The papers are available to all participants in the Convention on payment of a nominal fee; they fall into two sets, namely those for the General Sessions, and those for the Specialist Sessions, of the Convention. The papers will be republished in a special issue of Part B of the *Proceedings*, which will be announced later.

GENERAL SESSIONS

'An Electronic Calculator for Punched-Card Accountancy' by **L. Knight** (Paper No. 1867 M)

'Remote Position Control and Indication by Digital Means' by **W. S. Elliott, M.A., R. C. Robbins, B.A., and D. S. Evans** (Paper No. 1897 M)

'The Manchester University Mark II Digital-Computing Machine' by **T. Kilburn, D.Sc., Ph.D., M.A., D. B. G. Edwards, Ph.D., M.Sc., and G. E. Thomas, Ph.D., M.Sc.** (Paper No. 1926 M)

'The Use of Cyclic Permuted Codes in Relay Counting Circuits' by **G. C. Tootill, M.A., M.Sc.** (Paper No. 1944 M)

'Digital Computers and the Load-Flow Problem' by **J. M. Bennett, Ph.D.** (Paper No. 1957 M)

'A Transistor Digital Computer' by **E. H. Cooke-Yarborough, M.A., R. C. M. Barnes, B.Sc.(Eng.), J. Stephen, Ph.D., and G. A. Howells** (Paper No. 1964 M)

'Transistor Arithmetic Circuits for an Interleaved-Digit Computer' by **R. C. M. Barnes, B.Sc.(Eng.), G. A. Howells, and E. H. Cooke-Yarborough, M.A.** (Paper No. 1992 M)

'An Interleaved-Digit Magnetic-Drum Store for a Transistor Digital Computer' by **J. H. Stephen, Ph.D., and E. H. Cooke-Yarborough, M.A.** (Paper No. 1999 M)

'Sorting of Data on an Electronic Computer' by **D. W. Davies, B.Sc.** (Paper No. 2014 M)

'The Use of the Pilot Ace for Testing a New Design of Proton Synchrotron' by **G. G. Alway, B.A.** (Paper No. 2032 M)

'A Transistor Digital Computer with a Magnetic-Drum Store' by **T. Kilburn, M.A., Ph.D., D.Sc., R. L. Grimsdale, M.Sc., Ph.D., and D. C. Webb, B.Sc.** (Paper No. 2043 M)

'A Rapid Digital-to-Analogue Convertor for Numbers having Eleven Binary Digits' by **F. Beckett** (Paper No. 2044 M)

'The HEC4E Computer' by **R. Bird, M.Sc.(Eng.)** (Paper No. 2052 M)

'The Programme-Controlled-Computer: A Digital Computer for Commercial Applications' by **E. J. Guttridge and R. P. B. Yandell, B.Sc.** (Paper No. 2063 M)

'Use of Interpretation Routines on a General-Purpose Digital Computer for the Design of Linear and Non-Linear Control Systems' by **W. D. Worthy, M.A.** (Paper No. 2066 M)

'The Digital Computer as an Aid to the Electrical Design Engineer' by **B. Birtwistle, M.Sc., and Beryl M. Dent, B.Sc.** (Paper No. 2092 M)

'The Acoustic Delay Line Electronic Calculator' by **J. Tempel** (Paper No. 2093 M)

'Mercury: A High-Speed Digital Computer' by **K. Lonsdale and E. T. Warburton** (Paper No. 2095 M)

'Deuce: A High-Speed General-Purpose Computer' by **A. C. D. Haley, M.A.** (Paper No. 2096 M)

SPECIALIST SESSIONS

'Reading of Magnetic Records by Reluctance Variation' by **T. Kilburn, M.A., Ph.D., D.Sc., G. R. Hoffman, B.Sc., Ph.D., and P. Wolstenholme, B.Sc.** (Paper No. 1946 M)

'The Use of Electromagnetic Delay Lines in the Manchester University Mark II Digital Computing Machine' by **G. E. Thomas, M.Sc., Ph.D.** (Paper No. 1990 M)

'The Programming Strategy used with the Manchester University Computer' by **R. A. Brooker, M.A.** (Paper No. 2013 M)

'The Method of Lanczos for calculating the Characteristic Roots and Vectors of a Real Symmetric Matrix' by **R. A. Brooker, M.A., and F. H. Sumner, Ph.D.** (Paper No. 2017 M)

'Wire Type Acoustic Delay Lines for Digital Storage' by **G. G. Scarrott and R. Naylor, M.Sc.** (Paper No. 2027 M)

'The Solution of Non-Linear Heat-Conduction Problems on the Pilot Ace' by **E. L. Albasiny, B.A.** (Paper No. 2033 M)

'A Digital Store using a Magnetic Core Matrix' by **A. A. Robinson, M.A., Ph.D., V. L. Newhouse, Ph.D., M. J. Friedman, B.Eng., D. G. Bindon, and I. P. V. Carter, M.A.** (Paper No. 2040 M)

'A Sonic Delay Line Storage Unit for a Digital Computer' by **J. W. Fairclough, B.Sc.Tech.** (Paper No. 2041 M)

'A Magnetic-Tape Auxiliary Storage System for the Edsac' by **M. V. Wilkes, M.A., Ph.D., and D. W. Willis, M.A.** (Paper No. 2051 M)

'Electromagnetic Delay Networks for Digital Storage' by **G. G. Scarrott, W. J. Harwood, B.E., and K. C. Johnson, M.A.** (Paper No. 2055 M)

'The Design and Use of Logical Devices using Saturable Magnetic Cores' by **G. G. Scarrott, W. J. Harwood, B. E., and K. C. Johnson M.A.** (Paper No. 2065 M)

'Some Storage Circuits based on Valves' by **G. C. Tootill, M.A., M.Sc.** (Paper No. 2073 M)

'A Magnetic-Tape Digital-Recording Equipment' by **A. A. Robinson, M.A., Ph.D., F. McAulay, A. H. Banks and D. Hogg** (Paper No. 2077 M)

'A Multi-Input Analogue Adder for Use in a Fast Binary Multiplier' by **D. B. G. Edwards, Ph.D., M.Sc.** (Paper No. 2078 M)

'The Transfer-Track Method of Magnetic-Drum Operation' by **J. E. Flood, Ph.D., R. S. Hopkins, B.Sc.(Eng.), and H. A. Showell** (Paper No. 2081 M)

'The Magnetic Storage Drum on the Ace Pilot Model' by **D. A. Clayden, L. J. Page, B.Sc., and C. F. Osborne** (Paper No. 2090 M)

'The Design and Operation of a Parallel-Type Cathode-Ray-Tube Storage System' by **D. B. G. Edwards, Ph.D., M.Sc.** (Paper No. 2094 M)

District Meetings

Arrangements for District Meetings other than those in the area of a Local Centre

1956			**HATFIELD** (At the Hatfield Technical College at 7 p.m. Tea at 6 p.m.)
March	20	*Tuesday*	E. C. CHERRY, D.SC. 'Information Theory'*
			READING (At the George V Room, George Hotel, King Street, Reading, at 7.15 p.m.)
March	19	*Monday*	B. L. GOODLET, O.B.E., M.A. 'The Nuclear Power Programme'*

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL REVIEW OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (FEBRUARY 1956)

See *Journal*, February 1956, page 126.

PART B. RADIO AND ELECTRONIC ENGINEERING (MARCH 1956)

Discussion on **A Transistor Digital Fast Multiplier with Magnetostrictive Storage** before the Radio and Telecommunication Section

March 1956 — AUDREY D. STUCKES, M.A. **Some Theoretical and Practical Considerations of the Johnsen–Rahbek Effect** (PAPER No. 2007 M)

March 1956 — D. R. CHICK, M.SC., B.SC., AND D. P. R. PETRIE, M.SC. **An Electrostatic Particle Accelerator** (PAPER No. 1869 M, JULY 1955)

March 1956 — S. E. HUNT, PH.D., D. P. R. PETRIE, M.SC., K. FIRTH, B.SC., AND A. J. TROTT **An Electrostatic Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale** (PAPER No. 1840 M, MAY 1955)

February 1956 — D. L. HOLLWAY, B.E.E., M.ENG.SC., D.SC.ENG. **An Electrolytic-Tank Equipment for the Determination of Electron Trajectories, Potential and Gradient** (PAPER No. 1837 M, MAY 1955)

February 1956 — D. L. HOLLWAY, B.E.E., M.ENG.SC., D.SC.ENG. **A Method of Tracing Electron Trajectories in Crossed Electric and Magnetic Fields** (PAPER No. 1838 M, MAY 1955)

Not yet reviewed — J. WILLIS, B.SC.(ENG.) AND N. K. SINHA, PH.D., B.SC.(ENG.) **Non-Uniform Transmission Lines as Impedance Transformers** (PAPER No. 1961 R)

Not yet reviewed — G. CRAVEN AND L. LEWIN **Design of Microwave Filters with Quarter-Wave Couplings** (PAPER No. 2001 R)

Written discussion on **Theory of Imperfect Waveguides: The Effect of Wall Impedance**

Not yet reviewed — F. R. CONNOR, M.SC., B.SC.(ENG.) **An Ultra-High-Speed Oscillograph** (PAPER No. 1931 R)

March 1956 — R. L. BEURLE, B.SC.(ENG.) **A Comparison of the Noise, and Random Frequency and Amplitude Fluctuations in Different Types of Oscillator** (PAPER No. 1968 R)

March 1956 — R. G. MEDHURST, B.SC., AND G. F. SMALL, B.SC.(ENG.) **An Extended Analysis of Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex** (PAPER No. 2006 R)

Not yet reviewed — C. R. BARNARD **A Method of Increasing the Ambient Illumination of Radar Operations Rooms without Reduction of Signal Detection Threshold** (PAPER No. 2023 R)

Discussion on **A Study of some of the Properties of Materials affecting Valve Reliability** before the South-West Scotland Sub-Centre and the South Midland Radio Group

January 1956 — E. D. R. SHEARMAN, B.SC.(ENG.) **The Technique of Ionospheric Investigation using Ground Back-Scatter** (PAPER No. 1915 R, OCTOBER 1955)

January 1956 — E. D. R. SHEARMAN, B.SC.(ENG.) **A Study of Ionospheric Propagation by Means of Ground Back-Scatter** (PAPER No. 1914 R, OCTOBER 1955)

January 1956 — R. W. MEADOWS, B.SC.(ENG.) **An Experiment to Test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km** (PAPER No. 1901 R, SEPTEMBER 1955)

January 1956 — F. J. M. LAVER, B.SC., AND H. STANESBY **An Experimental Test of Reciprocal Transmission over Two Long-Distance High-Frequency Radio Circuits** (PAPER No. 1904 R, OCTOBER 1955)

January 1956 — W. J. BRAY, M.SC.(ENG.), J. A. SAXTON, D.SC., PH.D., R. W. WHITE, B.SC., AND G. W. LUSCOMBE, B.SC.(ENG.) **V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication** (PAPER No. 1920 R, OCTOBER 1955)

PART C. MONOGRAPHS (MARCH 1956)

(*Reviews of monographs are not published in the Journal*)

I. A. HARRIS **The Theory and Design of Coaxial Resistor Mounts for the Frequency Band 0–4 000 Mc/s** (No. 132 R, May 1955)

I. THOMAS, B.SC. **Second-Order Torque Components in the Schrage Motor Operating at Synchronous Speed** (No. 133 U, May 1955)

H. K. MESSERLE, M.ENG.SC., B.E.E., AND R. W. BRUCK, B.SC., B.E.
Steady-State Stability of Synchronous Generators as affected by Regulators and Governors (No. 134 S, June 1955)

M. E. ZEIN-EL-DINE, PH.D., AND H. TROPPER, PH.D.
The Electric Strength of Transformer Oil (No. 135 S, June 1955)

LUCY J. SLATER, M.A., PH.D. **A Short Table of the Laguerre Polynomials** (No. 136, June 1955)

E. G. C. BURT, B.SC., AND O. H. LANGE, DR.RER.NAT.
Function Generators based on Linear Interpolation with Applications to Analogue Computing (No. 137 M, June 1955)

R. A. BAILEY, PH.D., B.SC.
A Resonant-Cavity Torque-Operated Wattmeter for Microwave Power (No. 138 R, June 1955)

S. DEMCZYNSKI, DIPL.ING. **The Correlation between Decay Time and Amplitude Response** (No. 139 R, July 1955)

ULRIK KRABBE, PH.D.
The Residual Time-Constant of Self-Saturating (Auto-Excited) Transductors (No. 140 M, July 1955)

A. G. MILNES, M.SC., AND T. S. LAW, B.SC.
A.C. Controlled Transductors (No. 141 M, August 1955)

J. R. M. VAUGHAN, B.A. **A Millimetre-Wave Magnetron** (No. 142 R, August 1955)

D. J. WOOTTON, B.SC., AND A. F. PEARCE, PH.D.
A Reflex Klystron Oscillator for the 8–9mm Band (No. 143 R, August 1955)

P. HAMMOND, M.A.
The Magnetic Screening Effect of Iron Tubes (No. 144, August 1955)

R. E. COLLIN, B.SC., PH.D., AND JOHN BROWN, M.A., PH.D.
The Calculation of the Equivalent Circuit of an Axially Unsymmetrical Waveguide Junction (No. 145 R, August 1955)

D. G. TUCKER, D.SC., AND G. G. JAMIESON
Discrimination of a Synchronized Oscillator against Interfering Tones and Noise (No. 146 R, August 1955)

A. E. KARBOWIAK, PH.D.
Microwave Propagation in Anisotropic Waveguides (No. 147 R, August 1955)

E. D. FARMER, B.A.
Junction Admittance between Waveguides of Arbitrary Cross-Sections (No. 148 R, August 1955)

R. E. COLLIN, B.SC., PH.D., AND JOHN BROWN, M.A., PH.D.
The Design of Quarter-Wave Matching Layers for Dielectric Surfaces (No. 149 R, September 1955)

PROFESSOR E. G. CULLWICK, O.B.E., M.A., D.SC., F.R.S.E.
Electromagnetic Momentum and Electron Inertia in a Current Circuit (No. 150, September 1955)

C. P. ALLEN, B.SC.(ENG.), AND G. M. CLARKE, M.A., PH.D.
Interpretation of Wavelength Measurements on Tape Helices (No. 151 R, October 1955)

R. F. MILLAR, M.A.
An Approximate Theory of the Diffraction of an Electromagnetic Wave by an Aperture in a Plane Screen (No. 152 R, October 1955)

A. AKED, B.SC.
Peak-Voltage Measurements of Standard Impulse Voltage Waves (No. 153 M, November 1955)

J. F. BARRETT AND J. F. COALES, O.B.E., M.A.
An Introduction to the Analysis of Non-Linear Control Systems with Random Inputs (No. 154 M, November 1955)

I. J. GOOD, M.A., PH.D.
Some Terminology and Notation in Information Theory (No. 155 R, November 1955)

J. ALLISON, B.SC.(ENG.), PH.D., AND F. A. BENSON, M.ENG., PH.D.
Attenuation and Permeability of Ferromagnetic Waveguides between 9 000 and 9675 Mc/s (No. 156 R, December 1955)

PROFESSOR G. H. RAWCLIFFE, M.A., D.SC., AND B. C. MCDERMOTT, B.SC.TECH.
The Theory of Third-Harmonic and Zero-Sequence Fields (No. 157 U, December 1955)

W. J. POHL, M.SC.
Mutual Heating in Transmitting-Valve Filament Structures (No. 158 R, December 1955)

Written discussion on **A Note on the Surface Loss in a Laminated Pole-Face**

Written discussion on **Steady-State Stability of Synchronous Generators as affected by Regulators and Governors**